Educ.

Vol. XXIX, No. 5 *Whole No. 250*

MAY, 1929

SCHOOL SCIENCE AND MATHEMATICS

FOUNDED BY C. E. LINEBARGER

A Journal for all SCIENCE AND MATHEMATICS TEACHERS

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Published by THE CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS
Publication Office: 404 N. WESLEY AVE., MOUNT MORRIS, ILLINOIS
Business Office: 1439 FOURTEENTH ST., MILWAUKEE, WISCONSIN
Editorial Office: 7633 CALUMET AVE., CHICAGO, ILLINOIS

Published monthly, October to June, Inclusive, at Mount Morris, Illinois *Price, $2.50 Per Year: 35 Cents Per Copy*
Entered as second-class matter March 1, 1913, at the Post Office at Mount Morris, Illinois, under the Act of March 3, 1879

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A WORD TO OUR CONTRIBUTORS.

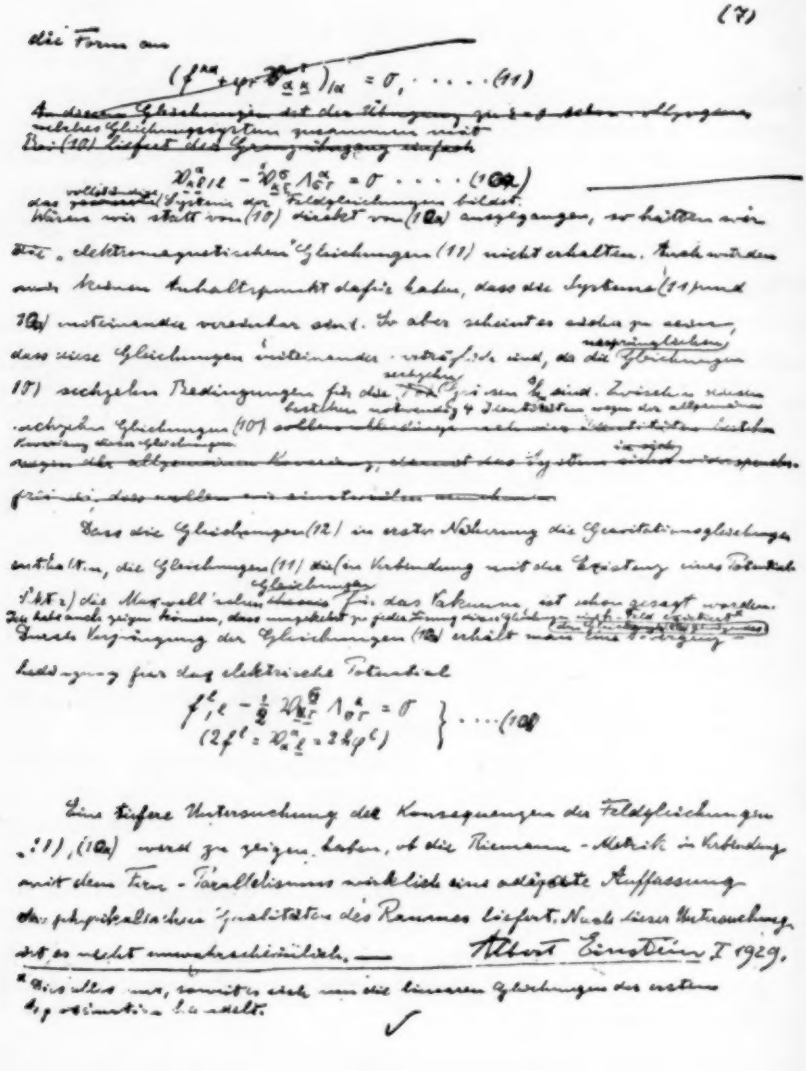
Articles for publication may be sent either to the Editor-in-Chief or to the proper Departmental Editor. Manuscripts should be typed, double spaced and written on one side of the paper. All drawings should be in India ink and on separate sheets. They may be of any convenient size. Contributors should constantly keep in mind that they are writing for the world's busiest people. In general, an article that cannot be read in ten or fifteen minutes will not be read by many. President Hoover's complete message to the extraordinary session of the Seventy-first Congress would fill less than five pages of this journal. The news item on the following page shows that an author is not always appraised on the basis of volume production. In accordance with this view it is our policy to publish many short articles in each issue rather than a few long ones.

Our editorial staff is made up of classroom teachers, each editor carrying a full load and doing the editorial work as an extra activity. We believe this makes them the better qualified for this work because they know school work as it is in practice. Each is not only a specialist in his own department but has also made a thorough study of educational methods and the relation of science to the entire field of education.

Because science cannot be sharply divided into separate divisions and pigeonholed accordingly, no attempt is made to divide each issue into departments. Many articles are equally suitable for two or more departments. If you have made an investigation that you believe contributes something of value to our readers, either in subject matter or in method of presentation, give us a brief report of your problem, the method used and the findings. By this plan your contribution will become interest-bearing immediately.

THE ORIGINAL MANUSCRIPT OF "ZUR EINHEITLICHEN FELD-THEORIE."

Through the courtesy of Wesleyan University, Middleton, Conn., we are enabled to reproduce a copy of one page of the newest scientific theory, the theory which combines the laws of mechanics and those of electricity into one law, as presented in the original manuscript by the author, Professor Albert Einstein. The manuscript of this remarkable document was purchased by Mr. George W. Davison and Mr. Albert W. Johnston, New


(7)

Albert Einstein I 1929.

York financiers and trustees of the university, and will be permanently kept and cared for in the Olin Library of Wesleyan University.

The manuscript "Zur Einheitlichen Feld-Theorie" was autographed by Professor Einstein at the bottom of the seventh page. The eighth page contains expressions of thanks to Professor Einstein's co-workers. Professor Einstein supplied his signature after arrangements had been made for the acquisition of the manuscript, and he signed the seventh page because the scientific part of his manuscript ends there. These seven pages, which contain the results of six years of Professor Einstein's deepest thought, represent the mathematical statement of a scientific theory, which it has been said that not more than twelve men understand at the present time. It is also said that Professor Einstein believes that it will be years before the world of science will be able to grasp fully all the details and implications of his theory and check up on his calculations. Even today science has not finished checking up on the calculations of the Einstein relativity theory.

It is especially significant of the character of the great mathematician that his only interest in the financial aspects of the transaction was that its sale should realize sufficient money to enable him and his wife to carry on the welfare work among university students in which both of them have long been much interested.

WHAT IS THE AURORA BOREALIS?

Popularly known as the northern lights, the aurora borealis is a phenomenon of the northern skies—a seemingly electrical effect, with flashing lights, often in a fan-shaped arch, seen only at night. The exact cause of the aurora borealis has never been satisfactorily explained. Latest researches lead some authorities to connect it with sun spots. Recent investigations seem to indicate that the northern lights do not interfere with radio transmission, as had been supposed.

Whatever their cause, the lights have been watched in awe by generations of observers. The name aurora borealis, according to Webster, is from the Latin "aurora," derived from the word for dawn, plus "borealis," meaning of the north. Aurora is a classical name of the Roman goddess of the dawn, and Boreas is the Latin name for the personification of the north wind.

The aurora is not confined to the north, however. There is also the aurora australis, so-called from the Latin word for south. Just as borealis means of the north, australis means of the south or southern hemisphere. The continent of Australia was named from this same Latin word for south.

MONMOUTH COLLEGE HONORS DR. ALICE WINBIGLER.

A half century of college teaching is the record of Dr. Alice Winbigler, who will retire in June with the title of Professor Emeritus. Monmouth College will also endow the chair of mathematics in her honor, for she has been head of the mathematics department for over a quarter of a century.

The record of Dr. Winbigler is unique in that she has served for all these years without a single leave of absence nor the privilege of a sabbatical year. Her wide travels and her advanced work in universities has all been done during the vacation months when the college was not in session.

The service of Dr. Winbigler covers two-thirds of the life of Monmouth College. More than 5,000 students have sat in her classes and her name appears on more than 1,700 of the diplomas held by graduates of the college. Dr. Winbigler herself is a graduate of the college with the class of 1877.

The term of service of Miss Winbigler is unique in college records. Hers, however, has not been only a great service in point of years. That she has been a truly great teacher is acclaimed by hundreds of her former students. It was her former students who started the move to endow the chair of mathematics in her honor and to name the commencement in June "Winbigler Commencement," a time to give their tribute to her.

In the time that Miss Winbigler has been at Monmouth the enrollment has doubled and the faculty increased to three times its former size. In the same time the value of equipment and the endowment have increased to thirty times their former value.

WHAT ARE THE CHANCES THAT——; A FEW QUESTIONS.

By Norman Anning,

University of Michigan, Ann Arbor.

The illustration used by Dr. Fry (vol. XXIX, No. 4, pages 357-359) suggests a few questions: When is it Sunday at the North Pole? In other words, at a place where the sun is always on a meridian, what day is it? When, among those meridians, there is one called the international date line, how does that fact simplify (complicate) our problem?

I have no quarrel with Dr. Fry's conclusion. If we accept the common-sense definition that at any place the time occupied by Sundays is exactly one-seventh of all the time there is, then we must agree that the chance that Peary reached the North Pole on Sunday is one-seventh of the chance that he reached the North Pole. If it is certain that he did, then Dr. Fry's statement is correct.

SOURCES OF ENERGY.[1]

By A. A. Knowlton,

Reed College, Portland, Ore.

"There are more things in heaven and earth, Horatio,
Than are dreamed of in your philosophy."

This quotation from Hamlet may be regarded as a complete statement of the conclusion which should have been drawn from the stalemate into which the controversy regarding the possible age of the solar system had degenerated at the end of the 19th century. In the previous article we reviewed, rather sketchily, the developments which led to that deadlock; in this we shall pass in equally rapid review some possibilities as to the sources of solar energy which have been revealed by the use of such modern conveniences as the electron theory, the nuclear atom, the quantum theory, and the theory of relativity.

The phenomena of radioactivity disclosed the existence of enormous stores of subatomic energy. With the growth of the conviction that matter is essentially electrical in nature, it presently became evident that there were three methods by which this energy of atomic constitution might be released and made available for conversion into the familiar forms of light and heat. These are:—

a. The spontaneous and explosive breaking down of complex atoms into simpler ones which we know as radioactivity.

b. The reverse process of building complex atoms out of simple ones. If one is at first inclined to interpose the objection that it is impossible for both these processes to result in the outflow of energy it is only necessary to point out the fact that precisely the same situation is encountered in ordinary chemical reactions. The *breaking down* of molecules of nitroglycerine liberates energy, and so does the *formation* of molecules of water. As we shall presently see it is quite certain that many atom building processes, if they occur at all, must be exothermic; that is, result in the outflow of energy.

c. If all atoms are built up out of equal units of positive and negative electricity one may suppose that, under suitable conditions, pairs of these opposite units may coalesce so perfectly that each will completely neutralize the field of the other at all points. Since the energy associated with these units lies in the strong

[1]The first section of this article appeared in the March number of this Journal.

electric fields by which they are surrounded, this absolute neutralization (if it occurs) must result in the complete conversion of this constitutional energy into the radiant form.

What contributions to solar energy may be expected from each of these sources? Quantitative answers to this question are fairly easy to obtain in the limiting cases, which assume that each transformation takes place completely and involves all the material of the sun. These answers, like similar ones which we have considered in other cases, will indicate the possible sufficiency or insufficiency of the energy sources under consideration. If either is definitely insufficient it may be rejected at once as *the* source of solar energy even though it may be *a* contributing source. If either is definitely sufficient the possibility that it does in fact furnish energy for the major part of the solar radiation must be considered in the light of such rather meager knowledge as we may have.

The hypothesis that the solar radiation is kept up by energy derived from radioactive processes within the sun has much to make it plausible and attractive. In the first place it is the only one of the three processes mentioned above with which we have direct laboratory experience. We know from first hand observations that radioactive transformations do take place and that they are accompanied by the liberation of quantities of energy which are large in comparison with the amounts of matter transformed. Also, helium is an end product of these transformations, and helium is abundant in the sun and stars. In fact the hypothesis has so many attractive features that one feels somewhat reluctant to subject it to the quantitative test which has wrecked so many a good hypothesis before it. The reluctance is amply justified. From the standpoint of the physicist seeking a useful hypothesis as to the source of the solar energy the quantitative relations of radioactivity turn out to be rather in the nature of a boomerang. The total energy which these processes may have supplied for solar radiation is insufficient to greatly extend the time scale of the solar system; but this is not the worst of it. The study of radioactive minerals gives evidence that the crust of the earth is even older than the geologists had thought, and this evidence is of a sort with which the physicist cannot well quarrel. Thus the first effect of the modern discoveries was to strengthen the case for the antiquity of the solar system without greatly increasing the visible supply of energy. Unless elements which are stable on earth become radioactive under solar condi-

tions, this source of energy, like those previously considered, must be dismissed as insufficient. What of this possibility?

There are really two cases to be considered. It is possible that under the extreme conditions of temperature and pressure existing in the interior of the sun and stars such every day materials as lead and iron may become radioactive, and it is also possible that deep within the core of the sun there may be a store of radioactive elements having atomic numbers higher than that of uranium (92).

As to the first of these hypotheses one can only say that changes in temperature from near the absolute zero to as high as it is possible to go in the laboratory are absolutely without effect upon radioactive phenomena. So far as one can judge the stability of nuclei is inherent in their structure and independent of external conditions. It is true that this conclusion (or any other) must be held rather tentatively when one extends it to such extreme conditions as undoubtedly exist deep within the sun, but it is also true that the contrary assumption must be justified by some more positive evidence than the mere fact that the interior of the sun is a very hot place. If no other more likely sources of energy appear this assumption will merit further consideration.

The hypothesis that there are elements in the sun having atoms heavier than those of uranium has little to commend it. Radioactivity is due to nuclear instability. The fact that all known elements having atomic numbers above that of bismuth (83) are radioactive affords strong presumptive evidence that no more than that number of excess positive charges can be arranged to form a stable group of nuclear size, at least under conditions existing on the earth. It seems unlikely that an increase of a few million degrees in temperature would increase nuclear stability.

Finally there is one rather direct bit of evidence which makes it seem unlikely that such radioactive transformations play any major part in the supply of solar energy. Helium is one of the end products of radioactivity. If these processes are extensive and constant during the whole life of a star we should expect a progressive increase in the amount of this gas, so that the older stars should be distinguished by their high helium content. No such progressive accumulation takes place. Upon the whole it appears that the radioactivity hypothesis must join the contraction theory as one of those of which it may be said that it was

good but not good enough. At some stage of solar history radioactive processes may have contributed their mite toward the colossal expenditures but they cannot have been the chief source of supply.

The other two possibilities (atom building and the complete neutralization of electrons and protons) have much in common. Each assumes that matter and energy are related as are heat and mechanical energy, so that one is convertible into the other. This convertibility is a well-known deduction from the theory of relativity but it may also be looked upon as an experimental result comparable with that obtained by Count Rumford in his famous experiments on the nature of heat. The increase of inertia (mass) of an electron with increasing speed is a fact as well established as is the production of heat by friction and affords direct laboratory evidence of the conversion of energy into inertia. Unfortunately the experimental evidence falls short of full and direct quantitative proof of the equivalence of the two forms since the conversion is always, under laboratory conditions, incomplete. This means that the constant of proportionality corresponding to the mechanical equivalent of heat must be obtained in some less direct way than that employed by Joule in the analagous case. The theory of relativity gives the value of this constant which is equal to the square of the velocity of light, so that the complete transformation of one gram of matter into energy (if it takes place) must liberate 9×10^{20} ergs.

The researches of the past twenty years have made it clear that all atoms are composed of similar parts, electrons and protons. A proton is the natural unit positive charge, an electron the equal unit negative charge, and the hydrogen atom consists of one proton about which a single electron revolves in an orbit which is relatively as large as that of the earth. It may be helpful to some to realize that the proton of which we have so much to say is nothing other than the familiar hydrogen ion ($H+$) of elementary chemistry. All other atoms are built up out of precisely similiar electrons and protons, all the protons and a portion of the electrons being compressed into a minute, positively charged nucleus. The work of Aston on isotopes has shown that the weights of most atoms are slightly *less* than would be expected from the number of protons and electrons which must be supposed to have united to form them. This indicates that if, as seems quite certain, these heavier atoms have at some unknown time and place been built up out of hydrogen atoms (or out of

the free electrons and protons which would constitute ionized hydrogen), this extra mass must have been disposed of by converting it into energy. That is, the atom building process is generally exothermic, and the amount of energy released in the process of forming an atom of any one of the heavier elements is equal to 9×10^{20} times the diminution in mass. It proves to be true that for most of the heavier elements approximately 0.8% of the mass of the hydrogen must be thus transformed. That is, the formation of one kilogram of any heavier element must result in the transformation of approximately 8 grams of hydrogen into 72×10^{20} ergs of radiant energy. This is an amount of energy somewhat nearly equal to that released by the burning of two thousand tons of the best coal.

If we divide the total energy radiated by the sun per year by its mass we find that the present rate of radiation amounts to a loss of 6.2×10^{10} ergs per year for each kilogram of solar mass. Since each kilogram of hydrogen undergoing transformation into a heavier element would release approximately 7.2×10^{21} ergs, it follows that a star which began life with a mass equal to that of the sun, which was originally wholly composed of hydrogen, and which radiated during its whole life at the sun's present rate would start out with an energy supply from this source sufficient to last it for a little more than 10^{11} years. If the original hydrogen content amounted to only 10% of the total mass the life of the star would still be about 10^{10} years which, you will remember is just about equal to the minimum allowable for the past life of the sun. It is clear that any sound judgment as to the adequacy of this source of energy depends upon having some idea as to the amount of hydrogen which may be assumed to be present in the youngest stars.

What are the possibilities as to the hydrogen content of stars of this group? That they do contain large quantities of hydrogen is well known from spectroscopic evidence. Eddington, however, advances reasons for supposing that a star containing as much as 10% of hydrogen would be so transparent that energy would escape far more rapidly than it actually does from stars of this class. He sets 7% as the maximum hydrogen content for even the youngest of the stars, thus reducing the possible past life of the sun to what is certainly a very narrow limit if this has been the chief source of energy. The result of the discussion is, then, that it is just barely possible that energy provided by the process of atom building may have supplied the major part of the

energy radiated by the sun. What other tests, if any, may be applied to this hypothesis?

It happens that quite recently evidence of an unexpected sort has been discovered which seems to make it quite certain that this process of atom building does not take place in the stars at all. The nature of this evidence will be considered in another article (by Dr. Roller) but if the conclusion is justified it appears that one need have little concern as to the sufficiency of the process. It is ruled out by more cogent evidence.

It appears that we are left with only the third of our possibilities (that of the mutual annihilation of protons and electrons) from which to provide a means of support for the prodigal solar expenditures. Here there is no question of sufficiency; or rather there is a very evident possible sufficiency. If the sun is radiating energy which is derived from the conversion of its mass into radiation it may have had any necessary length of life, provided that it started out with a large enough mass and did not increase the rate of radiation too greatly during the earlier stages. If, for example, our sun has radiated away half its mass at its present rate it has a past of something more than 10^{13} years, which is quite long enough to satisfy any one who has yet spoken.

But although this hypothesis is sufficient it presents some very evident difficulties. The most important of these is the intensely hypothetical character of the whole structure. We are getting rather far from the sound footing of experience. It is well when adventuring in such uncharted territory to make sure that we understand the hypotheses upon which we rely and their relations to well established facts. The particular hypothesis which we are to consider is derived from our accepted ideas as to the electrical nature of matter. A proton is a center of unknown character (perhaps only a geometric point) to which an intense electric field is attached. So far as our experience goes this attachment is permanent and the field itself indestructible. The whole energy of constitution of the proton resides in the field. This field, like all other fields about electric charges, may be modified by the movements of other charges in its neighborhood. The energy changes which result from these modifications are those which occur in the ordinary procedures of radiation and absorption, and never involve more than a minute fraction of the total energy of constitution. The process which we are considering goes far beyond this. It involves the complete destruction of the field, and it must be borne in mind that we have no

experimental evidence that such destruction ever takes place, and no very useful ideas as to the conditions under which it may be expected to take place. We are, however, at present interested in the question. Does this process go on within the sun and stars? Our justification for considering it at all lies in the failure of less speculative sources of energy, and our method must evidently be to ask ourselves whether the assumption of such atomic annihilation fits in well with the life history of the stars, as astronomers have read that history.

The sun is one among several billions of stars, an individual among many other similiar individuals from which it is distinguished by characteristics which are quite similiar to those which distinguish one man from another. Among these characteristics those of size, mass, color, and age are of the most interest for our present purposes. For many years every system of stellar classification has assumed that all stars go through the same sort of life cycle, and that the differences between individual stars are largely differences of age. Knowledge of these differences has increased greatly within recent years. It is of course out of place here to attempt to discuss in any detail the methods by which this information has been obtained, or even to describe more of the results than have a direct bearing upon our problem.[2] The matter of most interest to us is that methods of determining the size and mass of many of the stars have been worked out. The problem of measuring the mass and determining the radius of a star so distant that it appears as a point of light in the largest telescopes is, as any one will admit, quite a difficult one. And yet it appears to have been pretty well solved. The bolometer gives information as to the total radiation from the star, the spectroscope gives its approximate surface temperature. Intensity of radiation (quantity of energy radiated per unit area) is a known function of the temperature, hence a knowledge of total radiation and temperature is sufficient to determine total area and so the radius of the star. Also it appears that the luminosity of a star (total amount of light given off) is a known function of its mass. Thus we have at hand a great deal of knowledge as to the changes in size and mass which seem to go on during the life of a star. The conclusion is that stars are born large and heavy and hot, and that they grow smaller and lighter and cooler with age.

[2] Those who are interested in this will find in Eddington's "*Stars and Atoms*" a most fascinating popular account of these discoveries. Those who wish something more than the popular account will find it in "*The Internal Constitution of The Stars*" by the same author.

If this is true it discloses a state of affairs which fits in well with the hypothesis that the radiated energy comes from the inertial energy, or energy of constitution, of the atoms. The decrease in mass with age follows as a result of the gradual radiation of the mass, and the lower temperatures of the older stars are a result of their lessened mass. Certainly the hypothesis grows more attractive, seems less impossible upon acquaintance. If further investigations in the astrophysical field lend additional support to it we may presently come to regard the problem of the source of solar energy as solved. At present it is a promising lead, the only one left to us. After all this discussion we still cannot say positively that we have tracked the sun's energy to its source. Our present best guess is that the sun is radiating away its substance at the rate of some millions of tons per second. A few pounds of this radiant energy fall upon the earth and other planets while the rest of it goes on into outer space. What becomes of it there?

GAS GENERATOR

By Virgil H. Best,

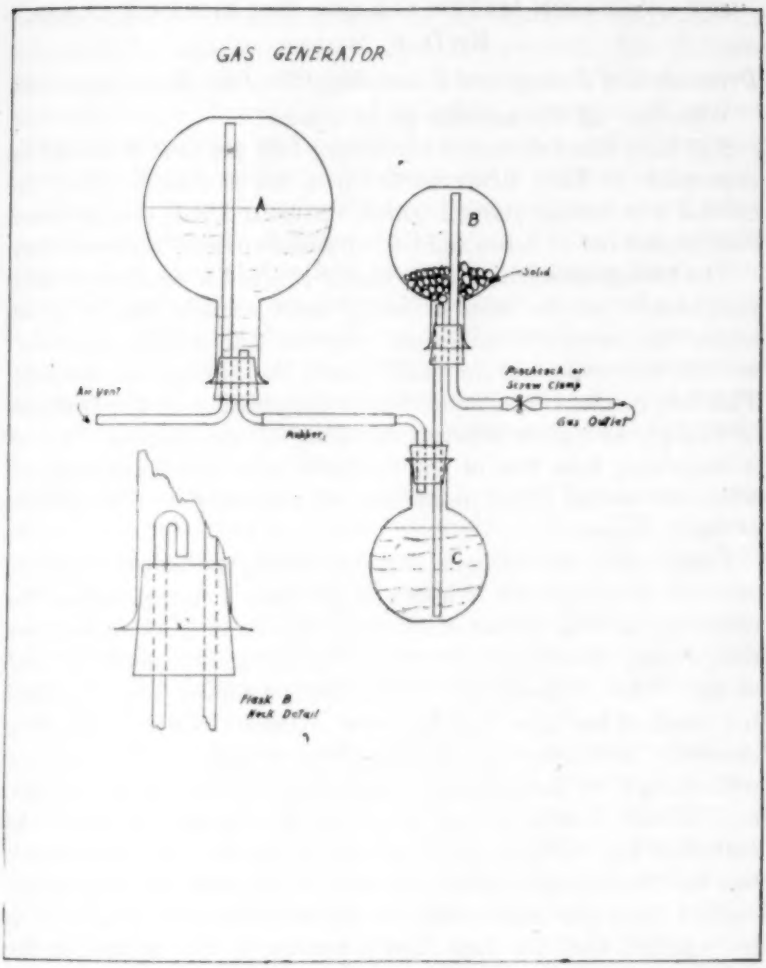
Garfield High School, Los Angeles, Calif.

The advantage of the following gas generator is mainly one of low cost as may be clearly seen from its construction. It has one more decided advantage however, in that by raising flask "A" which holds the liquid to a sufficient height, any desired pressure of gas may be obtained.

The action of the generator is self-explanatory I think. About the only thing to keep in mind in setting it up is that flask "A" should have a capacity equal to "B" and "C" combined. Also that the liquid, if it is all in "C" and "B," should not reach to the opening in the gas outlet tube in "B." Flask "A" and "B" should be joined by a rubber tube so "A" can be filled in an upright position, and then inverted at a suitable height. The whole apparatus may be mounted on a single ringstand with three burrette clamps or rings.

If one has trouble with the solid material clogging the tube joining "B" and "C" a goose neck tube as shown in the enlarged view of the neck of flask "B" may be used. Also with some materials it might be wise further to protect this tube opening by surrounding with glass beads or broken bits of glass.

Because of the ease of obtaining higher pressures I find it very



convenient in saturating solutions with a gas to pass the gas through several bottles connected together in series, thus exposing it to the liquid for a much greater time and distance.

Dunwoody Industrial Institute, Minneapolis, Minn., will give any instruction it has to offer to anybody, at any time, and for any length of course. The institute was founded 14 years ago with a student body of 40; enrollment today is about 5,000. Boys and young men dropping out of school or college are prepared for a wage-earning job, and additional training is given as opportunity offers, in order to fit students for higher wages. During the 14 years approximately 65,000 men have received the advantages of day, part-time, and evening instruction in the institute.

OUT-OF-SEASON MATERIALS FOR THE BIOLOGY CLASS.

By D. F. Miller,

Department of Zoology and Entomology, The Ohio State University.

Where do all the animals go in winter?

Not long ago a university professor told me that it would be impossible to have living earthworms for a class because the ground was frozen, though within the hour I had seen a dozen such worms out of doors and had obtained some of their cocoons.

The biological sciences have finally reached a position of such significance on the curriculums of most schools that it is no longer the custom to have just "anyone with a light schedule" or "the newcomer on the staff" teach the biology on the side. This has resulted in a much better preparation of the teachers of biology and more efficient handling of the courses. Yet it is surprising how few of the teachers have any knowledge of where to secure living materials, so necessary to the success of their subject.

I have often had students, many of them experienced teachers, stare in bewilderment if asked to produce a living animal for class use, even in spring or summer, and most of them suppose that during the rest of the year living things are not to be had at all. This is probably because their training has consisted too much of the type that has been characterized as "reviewing preserved specimens in the laboratory morgue." This may be well enough for learning the morphology of type forms but the new teacher nearly always brings to his younger students the materials and methods of his college or university, a fact which has too frequently resulted in some very poor teaching when viewed from the standpoint of the secondary student. It is my opinion that the fault lies primarily in the failure of the colleges and universities to give to their students who are going out to teach, any methods which will be useful to them in their later work.

Knowing of the widespread existence of this condition it seems worth while to offer a few suggestions for the finding of living animals "out of season." It is understood, of course, that differences in location will vary the possibilities, and many things not mentioned here will suggest themselves to the teacher.

Minute forms for the microscope. Perhaps the simplest and most abundant source of material of this kind is the ordinary infusion. The teacher should have the students get their own material for the culture, as: leaves, dead grass, straw, sticks,

weeds, etc., making notations as to locations and drawing comparisons and conclusions from the results. The cultures can be arranged in quart jars and labeled. The water may be examined in a few days and as often thereafter as wished. Detailed structures and names should be avoided with young students, habits and behavior being more important.

Sponges. Numerous freshwater sponges abound in our lakes, ponds and streams, growing on logs and stones, and may be obtained if the teacher has learned to recognize them. But unless he has, attempting to get them may be a waste of time.

Polyps. Usually the teacher is familiar with the little freshwater polyp, hydra. It may be difficult to find in winter unless there is an inside pool or tank with plants in it. If one is started earlier in the season it can be stocked with hydra and they make fascinating animals for class use.

Parasites and parasitism. Regardless of the season there are always numerous sources of materials for this. The students will not be averse to bringing a small bottle of fleas from their pet dog or cat, and lice and mites from chickens. If there is a slaughter house or packing house in the community a variety of intestinal worms (roundworms and tapeworms) may easily be had. The livers and intestines of wild rats are also good sources for tapeworms.

Earthworms. Any manure pile, old hay or straw stack, or heap of dead leaves will protect the ground beneath it so that earthworms can readily be found even when snow covers a frozen surface. In the manure pile can be found the manure worm and sometimes its cocoons. Leaves, mud and debris from pools, even when covered with ice, will often yield a number of very small aquatic earthworms if kept a few days in a jar of water in the class room. Such a jar stands on my table at present with dozens of these worms waving from the muddy surfaces of the leaves.

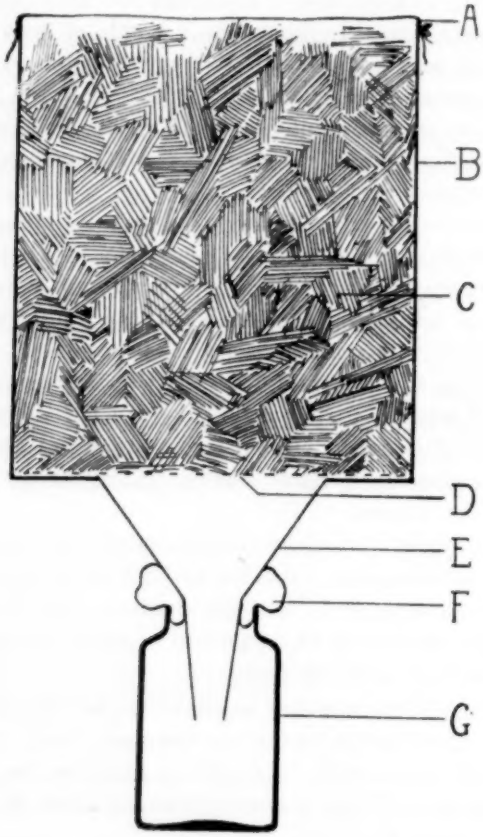
Shellfish. Snails and clams need scarcely be mentioned, as most people will have no difficulty getting them from the stones and mud in streams and from under stones and logs on land. They are easy to keep in an aquarium or cage, and they become active if placed in a warm room.

Arthropods. Crawfish are available at all times and are to be found in their usual haunts in streams where they may be caught in dip nets or by hand in shallow water. They live easily in captivity if the water is changed often or aerated by

plants. Turn over the large stones in a rapidly flowing brook where the water is not frozen, and you will likely find the nymphs of mayflies and stoneflies, and aquatic isopods.

Stalks of corn and large weeds, if split open, will furnish the larvae and pupae of many kinds of borers, and potted plants in the home or greenhouse are often hosts to plant lice and mealy bugs. Any child can collect cocoons from trees, fences and shrubbery. By scraping away the dead leaves that accumulate in a woods one will soon come upon groups of beetles or their larvae, as well as other insects and worms. In the March (1929) issue of this journal I have described a method of keeping an ant nest in the schoolroom throughout the year.

The Berlese funnel is a convenient and simple apparatus for getting the small forms, like insects and spiders, from fallen leaves and grass. The figure shows a sectional view of such a funnel, which the students will gladly make and use. A large



can, such as a lard can (B, in the figure), has a hole cut in the bottom and a big funnel E soldered over it. A false bottom, D, made of wide mesh wire screen is placed in the can which is then loosely filled with leaves, grass, weeds, etc., C, and covered with a piece of cheesecloth, A. The end of the funnel is placed in the mouth of a large bottle or jar, G, and sealed with a cotton plug, F. As the material gradually dries out on top the inhabitants will migrate down and be captured in the jar, which can contain alcohol if the specimens are not wanted alive.

The cockroach is with us throughout the year and had just as well serve a useful purpose as well as being a pest. Students can catch them by hand or trap them in a baited lard can. Packing and slaughtering houses will usually be able to furnish an unlimited supply of roaches. Their intestines quite often contain gregarines, interesting parasitic protozoa. During the greater part of the year flies may also be found around these houses.

Vertebrates. Almost any commercial hatchery will be quite willing to furnish a series of partly incubated eggs (if you promise a little advertising by saying where they were obtained) to show how a vertebrate develops. In smaller towns or country schools a borrowed incubator offers many attractive possibilities for a class. Fish, mice, rats and sparrows can be caught at all times and used alive. Though I have not mentioned many ready sources of materials the list is already long for this type of article and once started upon the hunt for living animals the teacher and class will find it easy to supply their needs.

Naturally enough the complaint will be heard that it is difficult to get many of these things in a locality where the weather is severe and snow and ice are common, or that much time and work would be involved. To the first complaint I wish to say that trips and collecting in such weather are real sport and offer to both students and teacher a chance to learn the unusual. As to the second, let me beg the teacher not to do this work alone and thus rob the students of the opportunity of learning and seeing where things live in nature. Yet for your own sake go with them for it is not necessary to be able to answer all their questions to keep their respect. Let it be known that you, too, are exploring. If at times you are unable to obtain some of the things you'd like to have for class it is a safe rule to ask the students. It's surprising how many things they can and will get if the teacher shows an interest and permits them to demonstrate for the rest of the class.

ON THE DISCRIMINANT OF THE CUBIC EQUATION.

By Raymond Garver,

University of California at Los Angeles.

The derivation of the discriminant of the general cubic equation, together with a study of the relation between its value and the nature of the roots of the cubic, is a topic of some importance in the elementary theory of equations. Cajori, in his Theory of Equations, obtains the discriminant as the constant term (except for sign) of the so-called equation of squared differences; Dickson, in his First Course in the Theory of Equations, obtains it with the aid of the algebraic solution of the cubic. Either of these methods is satisfactory; however, in the present paper I present another derivation which seems to possess certain advantages. First, it does not require the solution of the cubic, which seems desirable. Second, and more important, it employs a transformation at least as simple as that given by Cajori, and one which in addition leads to a very simple graphical explanation of the relation between the discriminant and the nature of the roots of the cubic. While Dickson gives a graphical explanation on page 65 of his text, the algebra necessary to supplement the graphs is more complicated than that used in the present article.

It is of course well known that the general cubic can be reduced easily to the form

$$y^3+py+q=0. \tag{1}$$

We shall deal only with this form; its roots will be denoted by y_1, y_2, y_3, and using the relations between roots and coefficients we have at once $y_1+y_2+y_3=0$, $y_1y_2+y_1y_3+y_2y_3=p$, $y_1y_2y_3=-q$. Now to (1) apply the transformation

$$z=2p+3q/y. \tag{2}$$

In this connection a few general statements may be made. If $f(y)=0$ is an equation of the nth degree in y, the transformation $z=R(y)$, where $R(y)$ is a rational function of y, is to be interpreted as a transformation on the roots of $f(y)=0$. That is, we consider that these n roots are substituted successively for y in $z=R(y)$; each gives a value of z, and the n values of z thus obtained are the roots of a new equation of the nth degree in z, called the transformed equation. The transformed equation can, however, be set up without finding the roots of $f(y)=0$; if this were not so it is quite improbable that transformations would ever be of value. The general question of forming the new

equation in z is taken up in books and articles concerning the Tschirnhaus transformation, and need not be considered here. However, the following rule is easily justified: If $z=R(y)$ can be solved for y as a rational function of z, say $y=R_1(z)$, then the equation in z obtained by replacing y in $f(y)=0$ by $R_1(z)$ and simplifying will be the desired transformed equation. That is, each root z of the new equation will be connected with a root y of $f(y)=0$ by the relation $z=R(y)$. Simple transformations of this type are customarily taken up near the beginning of a course in the theory of equations; for example, the transformation to reduce the roots of the given equation by a certain constant, that to multiply the roots by a constant, and that to replace the roots by their reciprocals. The material of this paper might be introduced at about the same point in the course as these other transformations.

To return now to (2), we see that it can obviously be put in the form

$$y=3q/(z-2p). \tag{3}$$

If we substitute this value of y in (1), clear of fractions, expand and divide out the common numerical factor q, we have as the transformed equation

$$z^3-3pz^2+4p^3+27q^2=0. \tag{4}$$

By (2), the three roots of this equation are $z_1=2p+3q/y_1$, $z_2=2p+3q/y_2$, $z_3=2p+3q/y_3$. Using the values of p and q as given above, and the fact that $y_1+y_2+y_3=0$, we may reduce the value of z_1 to the form $2(y_1y_2+y_1y_3+y_2y_3)-3y_2y_3=2y_1y_2+2y_1y_3-y_2y_3=y_1(y_2+y_3)+y_1y_2+y_1y_3-y_2y_3=-y^2+y_1y_2+y_1y_3-y_2y_3=-(y_1-y_2)(y_1-y_3)$. Similarly z_2 is found to equal $-(y_2-y_1)(y_3-y_2)$, while $z_3=-(y_3-y_1)(y_3-y_2)$. Thus if we define the discriminant D of (1) as the symmetric function $(y_1-y_2)^2(y_1-y_3)^2(y_2-y_3)^2$, we see at once that $z_1z_2z_3=D$. That is, the discriminant of (1) is given by the negative of the constant term of (4), so that $D=-4p^3-27q^2$. The determination of this value constitutes the first purpose of this paper.

We next wish to show how equation (4) can be used in deriving graphically the relation between the value of D and the number of real roots of equation (1). Since by (2) and (3), equation (4) has exactly as many real roots as (1), we may consider it instead of (1). The problem is then to investigate the real roots of (4), which we shall consider by graphing the function $F(z)=z^3-3pz^2+4p^3+27q^2$ and finding in how many points it intersects the z-axis. We shall assume a knowledge of the general shape of

the graph of a cubic polynomial of this type, and of the fact that its maximum point and minimum point can be found by taking the derivative of F(z) and setting it equal to zero. We also note that the graph will actually have a maximum point and minimum point unless p is zero, and that the maximum point will be to the left of the minimum point, since the coefficient of z^3 is positive.

It is easily seen that 0 and 2p are the values of z which make the derivative of F(z) vanish. The corresponding values of the function can be computed at once, and we have P_1, with coordinates 0 and $-D=4p^3+27q^2$, and P_2, with coordinates 2p and $27q^2$, as the maximum point and minimum point, though not necessarily in that order, of the graph. That is, if p is negative, P_2 will be to the left of P_1, and will be the maximum point. Its ordinate, for this case, is obviously greater than that of P_1. Now P_2 is certainly always above the z-axis.* If P_1 is also above, the graph can cut the z-axis in only point, and (4), and hence (1), will have just one real root. But the ordinate of P_1 is positive if, and only if, D is negative. Thus if D is negative, (1) has a single real root. On the other hand, if P_1 is below the z-axis, which it will be when D is positive, the graph must cut this axis in three points. Hence when D is positive, (1) has three real roots. In supplementing this paragraph with graphs, the reader will notice that when p is positive, D must be negative, while when p is negative, D may still be negative, or may be positive.

Finally, if $D=0$, P_1 will be on the z-axis, and we have a real double root. (The third root is also real in this case.) We also see directly from (4) that $z=0$ is a double root when $D=0$. From (3), $y=-3q/2p$ is then a double root of (1). Further, this is the only possible double root, and we have the interesting result that, if (1) has a double root, that double root is $-3q/2p$. The third root is then $3q/p$, since the sum must be zero.

*We rule out the trivial case $q=0$.

An instructional course in oil and gas production has been inaugurated in Pennsylvania State College, school of mines and metallurgy. It includes the study of natural gas and methods of development and production involved in petroleum-production engineering. Two advisory groups, composed of leading men in the oil and gas industries, will cooperate with the school in carrying out the educational project and in establishing a research program to aid the oil and gas industries of the State.

AN APPARATUS FOR DEMONSTRATING THE FUNDAMENTALS OF RADIO.

By Paul E. Klopsteg, Ph. D.,

Director of Development, and Manufacturing
Central Scientific Company, Chicago.

Radio has as firmly established itself in the life of the nation as has the automobile. In the transmission and reception of radio are involved physical principles that are intensely interesting, yet difficult to teach. It is doubtful whether these principles can be made clear to any except a few brilliant students in discussions based on the textbook and in blackboard illustrations alone. The ordinary receiving set is interesting enough to the student, but as an educational apparatus it is of small value. It cannot make real to the student the electromagnetic wave that carries the music and speech from the broadcasting station, and without which there can be no radio. The nature of the electromagnetic wave is thus the fundamental thing, and unless the student knows something about it, his knowledge of radio cannot be considered fundamental.

The old-fashioned coherer outfit used in demonstrations for twenty-five years and more is quite inadequate as means for teaching the fundamentals. It is little better than a receiving set of standard pattern would be for the purpose. To be sure, it includes transmission as well as reception, but the important ideas of resonance and tuning remain obscure because, with such a set, tuning is out of the question.

Recent developments, and the perfection attained in the manufacture of certain types of three-electrode vacuum tubes, have made possible the design of an apparatus which meets most of the requirements that can be set up for a demonstration apparatus which will really teach the fundamentals of radio. For several years the writer has kept his attention on these requirements, with the objective in view of designing an apparatus which should show the various phenomena associated with electromagnetic waves within the confines of the classroom; which should be so simple to operate that any teacher could successfully make the demonstrations; and which should be sufficiently powerful that the various effects of the waves could be convincingly shown without delicate apparatus. Such an apparatus has been developed, and the experiments that can be performed with it are among the most astonishing that can be shown in physics. The apparatus provides not only for impressive classroom demonstrations. The teacher who believes in

imparting scientific knowledge to the layman—the average citizen of his community—can use it in giving a popular lecture that will be most entertaining and instructive. He will find, incidentally, that engaging in such activities will be an effective method of getting in friendly touch with the community in which he labors.

The apparatus consists of three basic units: the high frequency electron tube oscillator with two sets of sending antennae, the power supply unit, and the tunable receiving antenna with indicating lamp. The high frequency oscillator comprises a simple circuit capable of generating oscillations of fixed frequency of about 100,000,000 cycles per second. (See Fig. 1.) Two power tubes of type UX210 are employed. These were

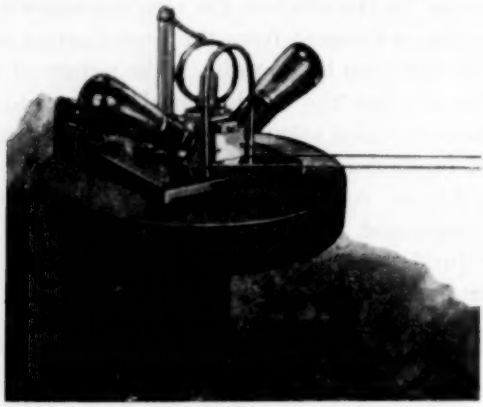


FIG. 1

chosen because they are standard and can be purchased from any good radio dealer, and because, of the common tubes, the UX210 is the best oscillator. Ample power is thus delivered into the oscillating circuit. The "sending" unit, consisting of tube sockets, condensers, inductive loop and accessory units, is mounted on a small bakelite base 11 cm. by 16 cm. With tubes in place, its extreme width is 30 cm. and height 14 cm. It is a most compact little unit. At the back is a triple connector socket. The plug which fits this socket is connected to the power supply unit. To operate the "sending" unit, the power supply unit is connected to a 110 volt 60 cycle source, and the multiple connector plug to the "sending" unit. As soon as these connections are made, the "sending" unit is oscillating.

The power supply unit consists of a transformer with several

secondary windings. One of the windings is used for lighting the filaments of the two vacuum tubes, and another for supplying the plate voltage. The latter is about 500 volts, and although caution in handling is advised, the circuits are so well insulated that, with ordinary care, there is no hazard whatever in the use of the apparatus.

The "sending" apparatus includes two sets of radiating antennae. One pair is attached directly to the terminals of the oscillator loop, and extend outward horizontally. The vertical antennae are connected to a coupling loop which may be variably coupled with the oscillator loop. Either pair of antennae may be used alone, or they may be used simultaneously, as described below.

The third unit of apparatus is the receiver. This is astonishingly simple. It consists of a tunable linear oscillator—a straight conductor of variable length—in the middle of which a small low-voltage incandescent lamp bulb is connected. Lighting of the filament is an indication of reception.

Included also in this group of apparatus is a small neon glow lamp, which is an excellent indicator of potential, and with which potentials existing at various points on the sending or receiving antennae may be explored.

The experimental procedure is very simple. With it the following interesting experiments, as well as others that will suggest themselves to the experimenter, can be performed.

1. Starting the Oscillator. Two UX210 tubes are inserted in the tube sockets. Connect the sending unit to the power unit by the triple connector plug. Then connect the power unit to the 110 volt 60 cycle supply. The sending unit should now be oscillating. To test whether it is oscillating, touch the exposed metal connected to the plate terminal of either tube with a piece of metal, or the graphite tip of a lead pencil, or the electrode of the neon test lamp. If the circuit is functioning, sparks appear at the contact, and the test lamp glows strongly. When the neon lamp is touched to the oscillator loop at the midpoint, where the plate supply voltage is led in, it will not glow at all, or only slightly. The reason is that this is a point of low potential in the oscillating circuit. It makes for great convenience and successful results in these demonstrations if the sending unit is supported on a wooden tripod stand. The presence of large masses of metal near the set should be avoided.

2. Measuring the Wave-Length. When the oscillator is

functioning, a quantity of electricity is surging back and forth at high frequency in the oscillator loop. The rate at which this surging takes place is determined by the inductance and capacitance of the loop, and the distributed capacitance of the conducting materials to which the ends of the loop are fixed. The oscillation of the charge in the loop constitutes a current of high frequency, associated with which there is an oscillating magnetic field which extends through the loop. At the instant the current reverses, the ends of the loop are at a large potential difference, and the current is zero. This condition gives rise to an electrostatic field across the ends of the loop. At the instant the current is maximum, the electrostatic field is zero. We may now trace the complete cycle, referring for greater clearness to Figs. 2-6 inclusive. We shall, in this process, not go into the details of

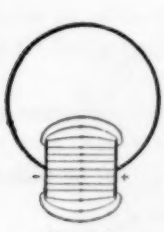


FIG. 2

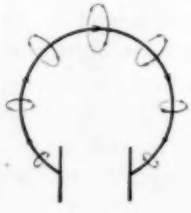


FIG. 3

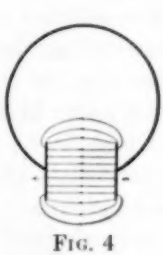


FIG. 4

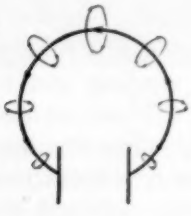


FIG. 5

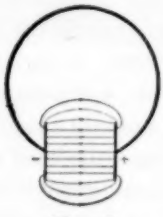


FIG. 6

functioning of the circuit, but take for granted that the vacuum tubes, supplied with power from the line, sustain the oscillations which we are examining more closely. In the figures the circular part represents the oscillator loop, which may be considered as having principally inductance; the parallel lines represent the capacitance associated with the loop.

Fig. 2 represents conditions at some instant; let us consider it the beginning of a cycle. There is no current in the loop; but the charges (in terms of the usual convention) are at maximum

displacement, so that we have maximum potential difference across the capacitance. Consider the right-hand side positive, the left, negative. The electrostatic force is maximum, with its direction as shown. At the instant we are considering, current begins to flow, because of the large potential difference between two points connected by a conductor—in this case the loop.

In Fig. 3 the current has reached maximum value. With the current are associated magnetic lines of force which began to appear at the instant the current started to flow, and which have reached maximum value now. The lines are at right angles to the loop, coming out of the paper within the loop, passing into the paper outside the loop. During this time the magnetic lines, which are closed figures approximating circles about the loop, are expanding outward with the velocity of light. The accompanying electrostatic field, everywhere perpendicular to the magnetic, and travelling with the latter, has been decreasing, and at the instant represented in Fig. 3, has vanished.

Because of inductance in the circuit, the current continues to flow in the same direction, which results in an increasing positive charge at the left, and negative on the right side of the condenser, as in Fig. 4. A maximum is finally reached, depending on the characteristics of the circuit. The electrostatic field incidentally is not limited as shown by the lines in the figure, but becomes established theoretically to an infinite distance with the velocity of light. When the current is maximum, the electrostatic field between the plates is zero.

Again, because of inductance, the current continues until the condition of maximum charge is reached, as in Fig. 6, which is identical with Fig. 2. We have now traced through a complete cycle of the oscillation, which is, in its simplest terms, an alternating current in the loop at exceedingly high frequency. Associated with this current are electrostatic and electromagnetic lines of force, mutually at right angles, traveling outward at the velocity of light. This traveling electromagnetic field constitutes a train of electromagnetic waves. One wave-length corresponds to a complete cycle of oscillation, represented in Figs. 2 to 6, as explained. Since the waves travel with the velocity of light, or 300,000,000 meters in one second, the length of one wave is the distance the wave travels during the time of one oscillation. In the apparatus which we are describing, this wave-length is—as we shall directly determine by measure-

ment—about 3.2 meters. Thus the time of one oscillation is 3.2/300,000,000 seconds, and the frequency is 300,000,000/3.2 or about 94,000,000 cycles (94,000 kilocycles) per second.

The motion of the electromagnetic field outward from the oscillating circuit represents a radiation of power, sustained by the power supply unit through the agency of the vacuum tubes. Such a loop is not a good radiating means, yet it is possible to detect the radiation, and to measure the wave-length.

To detect the radiation, we make use of the fact that if an electric circuit of proper inductance and capacitance is so placed relative to the oscillator that the electrostatic and magnetic lines which are radiated by the latter can induce a current in the former circuit, it will respond by having an oscillating current set up within it. The second circuit consists of a single loop, connected to a variable condenser of small capacitance. This condenser can be adjusted until the time of one oscillation in the circuit is the same as that in the oscillator. The combination of inductance and variable capacitance is called a wave-meter. When the wave-meter is held with its loop parallel to and anywhere within 30 cm. of the oscillator loop, and the condenser adjusted to the proper value, strong oscillations are set up in the wave-meter circuit. This adjustment is called tuning, and is identical with the tuning of an ordinary radio receiver. When the circuit is tuned it is said to be in resonance. To determine when the circuit is tuned we attach near one end of the loop the neon detector bulb. The bulb glows at resonance. Another indicator is a small flashlight bulb clipped across a short section (about 3 cm.) of the wave-meter loop. At resonance, the bulb lights brightly; in fact, unless one is careful, the bulb is easily burned out. The wave-meter has a 0-100 scale; a calibration chart supplied with the instrument converts scale readings to wave-length in meters.

3. Standing Waves on Wires. Another method of measuring wave-length is by the Lecher wire method. Standing waves are generated on a pair of parallel wires by coupling the oscillator to a small loop of copper rod, as shown in Fig. 1, to which the wires are connected. The loop is plugged into the sockets at the front of the oscillator, and two No. 24 bare copper wires are attached by twisting, one to each end of the loop. The wires are then stretched out parallel over any available distance, preferably greater than 5 meters, and supported at the opposite end by twisting them around a stick of dry wood, glass or other

insulator, and clamping the latter on a rod, or otherwise holding it so that the wires are parallel and taut. The glow lamp is now so mounted in the oscillator loop that it will glow brightly when the power is turned on, thereby indicating that the current is oscillating. Standing waves of potential and current are established on the wires. These waves become especially pronounced if the parallel wire system is "in resonance," i.e., if the length of the wires bears a definite relation to the wave-length. In case the ends of the wires are "open," a reversal in phase on reflection takes place, as in an open organ pipe; the open ends become points of maximum potential variation. If the ends are "closed," or bridged by a conductor, the potential variation must become zero, and these points will then be potential nodes. A conducting wire bridging the parallel wires is, in fact, used to "tune" the system to resonance. This is moved from the open ends towards the oscillator until a glow lamp, connected across the wires about 80 cm. away, glows most brightly. The condition of resonance is also indicated by the glow lamp connected to the oscillator loop; this shows sudden diminution in intensity when the nodal point is bridged. The other nodal points, at which zero values of potential exist between the wires can now be located by exploring the wires with a second glow lamp, bridging the latter across the wires. The lamp remains dark in regions of small potential difference, and bright where the potential difference is large. The nodal points of potential can be even more accurately located by sliding another conducting bridge along the parallel wires. As each nodal point is passed, the glow lamp in the oscillator will suddenly "wink," or grow dimmer; possibly it may go out. This behavior of the glow lamp is due to the energy which is being abstracted from the oscillator, which is maximum at resonance. The distance between adjacent points of zero and maximum potential, respectively, is a half wave-length of the electromagnetic waves produced in the oscillator.

4. Transmission and Reception of Radio Waves. The electromagnetic waves which originate in this apparatus are found by measurement (see preceding section) to be of the order of 3.2 meters in length. To increase the energy radiation from the oscillator, the latter is supplied with radiating antennae. These consist of two copper-plated brass tubes, one end of which is provided with a tapered plug for both mechanical support and electrical connection. As a first experiment, plug the antennae

horizontally into the sockets at the lower terminals of the oscillator loop. When the oscillator is started, the electrical surges travel to the ends of the antennae, and there is set up in the system a "standing wave" with maximum potential at the ends and maximum current at the mid-section, which is the oscillator loop. With the neon test bulb the potential distribution can be explored; and the current distribution is found by means of the small incandescent bulb, "clipped" across a centimeter or two of the oscillator loop, or of the antennae. Several test bulbs may be used simultaneously.

With the wave-meter we find that connecting the antennae slightly increases the wave-length. Knowing this wave-length, we can construct a linear oscillator to resonate at the frequency corresponding to this wave-length. The length of the oscillator (in the middle of which the flashlight bulb is inserted) is roughly adjusted to one-half the wave-length. If properly tuned, this "receiver," held horizontally about a meter away, responds to the waves being radiated, and the bulb glows brightly; fine adjustment may be made to the setting at which the bulb is brightest. The length of the "receiver" is another check on wave-length. Under good conditions, the lamp glows at several meters from the transmitter.

Receiving antennae in which several flashlight bulbs (about 7) are inserted are particularly effective in showing the current distribution in such an oscillator. A straight copper wire of the same length, on which several neon test lamps are distributed, shows the voltage distribution.

5. Demonstration of Polarization of the Waves. When the receiving antennae are parallel to the sending antennae, there is response; as the former are turned relative to the latter, the response weakens, and becomes zero at 90°. This shows polarization of the radio wave.

A vertically polarized wave of variable intensity can easily be produced. Plug the "coupling loop" into the socket in the base of the transmitter so that its single turn can be adjusted in position relative to the oscillator loop, by turning in the socket. Plug the one antenna into the upper end of the coupling loop, and the other into the socket from beneath. To do this, allow the base to protrude over the edge of the stand or table. Using any one of the receiving antennae mentioned, it will be found that there is maximum response with the "receiver" vertical, and zero response when it is horizontal.

6. Change in Power Radiated with Change in Coupling. With the single bulb antennae held vertically in one hand, change the coupling by turning the coupling loop in the socket. When the two loops are far apart, i.e., when the coupling loop makes a large angle with the oscillator loop, response is weak; when the loops are parallel, response is strong. This shows that more energy is "fed into" the antenna, and radiated, with close coupling.

7. Measurement of Electromagnetic Field Intensity. Connect a thermo-galvanometer to the receiving antennae in place of the flashlight bulb. Deflection of the pointer is proportional to the square of the current, hence to the energy in the linear oscillator, which must be roughly proportional to the energy radiated to the point at which the receiver is located. It is instructive to take readings of the meter at different distances from the transmitter, with the receiving antennae parallel to the transmitting antennae, and to take readings, at a given distance, as the angles between receiving and transmitting antennae are changed.

Exploration of the electromagnetic field in the standing waves on the parallel wire system described in Section 3 may be simply and easily accomplished by moving the thermo-galvanometer along, but not touching the wires. In this manner the maximum and minimum points of electric force are quickly found and demonstrated.

8. Composition of Two Plane Polarized Waves. This experiment is a beautiful illustration of a polarized wave of great intensity, composed of two plane polarized waves at right angles to each other. To perform the experiment, both sets of antennae —horizontal and vertical—are used simultaneously. The oscillator is started. The receiver responds in either position parallel to one of the antennae. It responds with great intensity at 45°, in the position bisecting the angle between the antennae; but in the other 45° position, at right angles to the first, there is no response.

The reason is that in the one pair of quadrants the oscillations are in-phase, and strengthen each other; in the other they are out-of-phase, and annul each other.

Whether the flashlight lamp or the thermo-galvanometer is used as the detector, the experiment is very striking. With the thermo-galvanometer in the receiving oscillator, at a given distance, relative values of the energy at different angles may be obtained.

9. Standing Waves in Space. Prepare a large metal reflecting surface of thin sheet copper, either on some convenient wall or in

a frame mounted on casters. For best results the surface should be at least 1.6 meters (5.3 feet) square. A larger screen gives better results. Seams should be carefully soldered. With the oscillator and antennae (either set or both) at a distance equal to any odd number of quarter wave-lengths from this reflector, standing waves are set up in the region between oscillator and screen.

These can be detected with the linear resonator, in the usual way. With the thermo-galvanometer detector, it is instructive to plot the field as a function of location between oscillator and reflector. Another check on wave-length may be obtained in this manner.

10. Transmission of Polarized Waves Through a Screen. This experiment, though it requires the construction of an accessory, is eminently worth while. A screen is needed, which can be constructed by boys in the class. The screen consists of a frame which may be 1.6 meters ($\frac{1}{2}$ wave-length) square, made of wood. Parallel copper wires (No. 24 bare) are fastened vertically to the frame, individually secured to small brass or steel wire nails, spaced about 4 inches. Waves from the transmitter with horizontal antennae can be demonstrated to pass readily through the screen; waves from the vertical antennae are completely stopped. This is the exact analogy of polarized light and a polarizing plate, like tourmaline.

It is difficult, if not impossible, in limited space to give an adequate idea of all the possibilities of this unique outfit. The demonstrator after familiarizing himself with it will find unlimited opportunity for interesting experimentation. For example, he can try the "grounded" antenna on transmitter and receiver; he can try various hook-ups for making the received signals audible, as in a loudspeaker, and then transmitting "dots" and "dashes"; he can experiment with reflection from a plane surface at various angles; or explore the field in the vicinity of the transmitter with the wave-meter and either flashlight bulb or thermo-galvanometer detector; or build a parabolic reflector of parallel wires or sheet metal and, with the vertical antenna in the focus, experiment with "beam" transmission. He can light a flashlight bulb simply by connecting its filament between his body and a point on the oscillator loop near the mid-point of the latter. He will find that the experimenting which he does will give him a much better understanding of the fundamentals of radio, thereby making his teaching of this absorbing branch of physics more effective.

THE SCIENCE OF THE ELEMENTARY SCHOOL AND ITS RELATION TO THE SCIENCE OF THE JUNIOR HIGH SCHOOL.[1]

By Gerald S. Craig,

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Subject matter specialists are apt to assume that their own content divisions have peculiar values which will cure the world of all of its ills. Until recently the selection of material for the curriculum has been left to them. The result is that in spite of the curriculum investigation of recent years our schools are still carrying much dead timber.

We are in a period when the content of our elementary school courses of study must be challenged. It is an age of propaganda and no field is more fertile for advertising and sales talk than the elementary school. Many protagonists of pet theories of finance, economy, and social reform are attempting to gain admittance of their materials as a part of the regular instruction of the public schools. The elementary schools are already overcrowded with categories which challenge assimilation in the program of study.

This tendency to crowd the elementary curriculum indicates an immediate problem for the educator, the problem of creating techniques of selection and evaluation, and the utilization of these techniques after they have been created to determine what is worthwhile. The day is probably not far distant when specific objectives must rest upon a more substantial basis than that of approval of the subject matter specialists.

The field of natural science under the caption of nature study, although one of the infant categories of the elementary school, is probably the most restrained by tradition. It has been hindered in its progress by the peculiar aesthetic and ethical philosophy which was created as its guiding principles by the nature enthusiasts themselves. Most frequently the harmful elements of the philosophy have been proposed by those enthusiasts who have had little contact or acquaintance with actual classroom situations. Nature study has been influenced but little by the progress that has been made in the fields of measurement, techniques of teaching, psychology and curriculum revision. It has remained comparatively static in the elementary schools and today its very presence in the curriculum is being challenged by many educators.

Some of the implications of this philosophy that have been distinctly in conflict with the point of view of elementary science have been the following:

[1]Read at the General Science Section of the twenty-eighth annual meeting of the Central Association of Science and Mathematics Teachers.

1. Nature study is best taught by those who have a distinctly rural background.

2. Nature study should remain entirely on an incidental basis.

3. It was assumed by many that children below the high school do not generalize, therefore scientific principles, laws, generalizations, have no part in the elementary school.

4. Nature study has frequently become a mere study of animate and inanimate objects.

5. Nature study has been representative of only a small segment of science, and that largely biological.

6. Nature study has been confined to a study of indigenous species. This has been advocated in a period in which the environment of man has been greatly widened by the radio, aeroplane, telephone and telescope.

7. Learning should depend entirely in nature study upon the first hand observation, experiment and conclusion of the child.

It is scarcely necessary to indicate that these definitions of nature study have made it difficult to administer it or to erect a practical teaching program by which it might flourish in modern times. Under the guidance of these principles natural science has frequently resulted in mere busy work and object lessons.

We need not wonder therefore that natural science has not succeeded in the public elementary schools. No subject can remain in this day and time in the elementary school curriculum unless it can prove its right to be there. It is time that we throw aside our high sounding abstract terms with which we have enshrouded the nature study in the elementary school and be willing to submit the objectives to the acid test of curriculum investigation. Science can only become an integral part of the elementary school when it has proven that the elements of learning that enter the first six grades are worthy of a place in the educational process.

What is the function of science in the elementary school? Obviously science is playing a very important part in modern life and yet it is evident that elementary science is not utilizing its most vital contributions. But just what are the contributions of science which are such an important part of our social heritage that they should be passed on from generation to generation? What scientific contributions are so vital that they should be included in the already overcrowded curriculum of the first six

grades? Answers to these questions on some vital basis seem essential in constructing a course of study in science. In the elementary school we are not concerned so much in starting boys and girls on the road to becoming scientists and naturalists, as in training them to become educated laymen.

Science may be defined as the interpretation of natural phenomena. There has been a wide spread feeling in the past that boys and girls could not generalize or interpret prior to the high school. This feeling is distinctly false. Children do generalize. Their generalizations, however, may be so elementary in many cases as to be recognized only with difficulty by the adult. It is our task to guide children to draw correct generalizations that are intrinsically worthwhile.

What principles, generalizations and conceptions of science should be revealed and made meaningful in the elementary school? The following criteria are proposed which are indicative of studies that may define the content of science for the elementary and high schools:

A. Certain objectives that are selected for elementary science should conform to those scientific conceptions (1) which, when understood, greatly influence the thought reaction of the individual; (2) which have modified thinking in many fields.

B. Certain objectives that are selected for elementary science should conform to those goals (information, skills and habits) in science that are important because of their function in establishing health, economy, and safety in private and public life.

C. Certain objectives that are selected for elementary science should conform to those facts, principles, generalizations and hypotheses of science which are essential to the interpretation of the natural phenomena which commonly challenge children.

It will be noted that these criteria may be equally as important in selecting objectives in the secondary school and even adult education as in the elementary school. Such criteria as these can be important factors in coordinating the science instruction in grades one to twelve.

A list of larger objectives of science, which have been found to satisfy the requirements[2] of the criteria which have been made are the following:

SCIENTIFIC CONCEPTIONS.

1. The universe, including the earth is very old.
2. The surface of the earth has not always had its present appearance and

[2]Craig, G. S. Certain Techniques Used in Developing a Course of Study in Elementary Science for the Horace Mann School. Teachers College Contribution to Education No. 276, Bureau of Publications, Teachers College.

is constantly changing.

3. Space is vast.

4. There are scientific hypotheses to explain the formation of the earth.

5. Present conditions are apt to persist a very long time on the earth; no catastrophe for the entire earth is probable for immense periods of time.

6. The earth's position and relation to the sun and moon are of great importance to the life upon the earth.

7. The earth is a member of the solar system.

8. Matter and energy cannot be created or destroyed.

9. All life has evolved from very simple forms.

10. Species have survived because by adaptations and adjustments they have become fitted to conditions under which they live.

11. There is an interrelation and interdependence of plants and animals.

12. Physical environment has great influence, not only upon the structural forms of life, but also upon society.

13. There are certain vital processes of the plant and the animal.

14. Man has modified plant and animal forms through a knowledge of nature's methods.

15. Some forms of life are minute.

16. There is a balance of nature.

17. Man has become an important determining factor of environment for plants and animals.

18. Man's success in adaption is largely the result of his mental capacities.

19. Chemical and physical change takes place according to definite laws of nature.

20. There are less than one hundred elements.

21. Every substance is one of the following:
(a) An element. (b) A chemical compound. (c) A mechanical mixture.

22. Chemical and physical changes are sources of energy.

23. Man has ability to control his environment through the knowledge and use of physical and chemical change.

24. There are three states of matter.

25. Changes of physical form of matter are due to changes of the energy of heat.

26. Forces in nature are operating continuously to produce changes in the physical and biological environment.

27. Solids, liquids and gas behave according to fixed physical and chemical principles.

Information Essential to Effective Social Life.

28. The most important fuels, their conservation and efficient utilization for power and heat.

29. The sources and uses of power.

30. The function and utilization of foods.

31. The principles of ventilation.

32. The conversion of mechanical energy into electricity.

33. Disposal of garbage and sewage.

34. The maintenance of soil fertility.

35. Economic value of plants and animals.

36. The major causes of ill-health and the contribution of science to the correction of these causes.

37. Changes in the weather are manifestations of cause and effect.

38. Major causes of accidents and their prevention.

39. Acquaintance with elementary laws of nature which are necessary for the health of the individual and the community.

40. Information about those appliances which science has developed and which are useful in making for greater comfort and convenience in the home and community.

41. Conservation of natural resources.

42. Purification of water for drinking purposes.

Natural Phenomena (not listed above).

43. The production, manifestation and properties of sound.
44. The principles of machines.
45. The principles of floating bodies.
46. The nature manifestation and properties of light.
47. The production, manifestation and properties of electricity.
48. The principle of gravitation and its manifestations.
49. The composition and importance of the atmosphere.
50. Methods of communication.
51. Methods of transportation.
52. The physical properties of matter.
53. Units of measurement, of volume, density and temperature.

Associated with Scientific Attitudes.

54. Man's conception of truth changes.
55. Hypothesis has a function in science.
56. It is desirable to have confidence in the scientific method.
57. Nature's laws are invariable.
58. There is a cause to every effect.

The majority of these objectives may enter education at all levels. One can continue to add new facts and interpretations concerning these objectives throughout life. They can have a part in the curriculum of the undergraduate and graduate college departments as well as in the elementary and secondary schools.

It is necessary, therefore, that the larger objectives which have been listed above be analyzed into its component elements. This has been done by techniques which we cannot discuss at this time. It is possible to reveal the elements of learning which are constituent parts of the larger objectives (scientific principle or conception). It is also possible to indicate in most cases the order of the elements of learning from simple to technical.

It has been found advisable to use these elements of learning as specific objectives of science. The elements of learning should be stated as far as possible in the form of declarative sentences. The advantage of the declarative sentence is that it is definite as to the learning involved. The elementary teacher needs definite goals—not topics, phrases, and clauses which at best offer but little guidance as to the learning involved. A sentence usually implies interpretation, not mere recognition and observation.

Elementary science through recent investigations and practice may be characterized by the following statements:

1. Elementary science is the interpretation of natural phenomena that is within the province of the first six grades.

2. Elementary science is designed primarily to assist boys and girls to become educated laymen.

3. Elementary science will be based on an organization of

elements of learning in science beginning with the kindergarten and extending through the sixth grade.

4. Elementary science will utilize recognition and observation as means to an end rather than an end in learning.

5. Elementary science is based on a well-balanced program of elements of learning which are carefully selected from the major fields of science—astronomy, biology, chemistry, geology and physics.

6. Elementary science will be revised and reorganized as progress in society, education, and science makes it necessary.

The future of science in elementary schools is most encouraging. Laymen, scientists and educators are interested in the development of this field. One prominent educator has gone so far recently as to say the greatest development in the next decade in elementary education will occur in science. In the not far distant future, science will be assuming its place along with the three r's in the elementary school.

It is true that at present we are limited by the fact that elementary teachers are not equipped to teach science. Two lines of activity should be pushed forward as rapidly as possible. One is the revision of the curriculum of teacher training institutions in order to provide them with the curriculum necessary to teach science. The other is the extension of training in service. Excellent results have been secured in several school systems in the past year. Several of our state educational departments are rendering teachers an excellent type of training in service.

Elementary teachers who have attempted science are most enthusiastic about it. They find that it is alive rather than static. The content is interesting to children and is inducive of wholesome attitudes toward school work. There is little doubt that the elementary school teachers will become the best advocates of science in the immediate future.

Science of the high school has unfortunately been built from the top down. With the development of science in the primary and intermediate grades, it will be built from the bottom up. Junior high school science should be constructed on the accomplishment of the elementary school, and should be a continuation of the development of the larger objectives. The larger objectives are the same for all levels. The difference lies in the specific objectives or meanings that are developed which are a part of the larger objectives.

As the elementary science program becomes a reality in our

school it will be necessary to revise our high school curricula. We will probably find that some of the material we are at present teaching in the junior high school will already have been accomplished in the elementary school. This probably will result in the promoting of general science in the junior high school.

There should be no sharp division between the science of the sixth grade and the seventh grade. There seems to be no apparent reason why seventh grade science should differ from sixth grade more than the sixth grade does from fifth. Each grade should be built on the preceding ones providing for sequence and extension of learning directed toward the larger objectives of science.

Such a program gives opportunity to make a greater application of the laws of learning than has hitherto been secured. The elements of learning of each grade level should be requisite to the learning on later grade levels. The learning of the elementary school need not be repeated in identical setting in the junior high school. Rather the curriculum of the grades I—XII should require that elements already learned be utilized in later learning and thus provide for frequency of use. Few fields of knowledge can be as easily organized on this basis as science.

Junior high school teachers should be conscious of what is being taught in the elementary school. Too frequently junior high school teachers are entirely ignorant of what is going on in the elementary schools. There is a growing demand from school systems for people who can become heads of departments of science from grades one to twelve. In this case department heads assist the teachers of the elementary school by giving expert advice. They also assist in coordinating the instruction on the various levels and have charge of the visual aids of instruction in science on all levels. At present there are very few people who are qualified to fill such vacancies.

LEAVE OF ABSENCE IN SCHENECTADY

Ten days' leave of absence with pay is allowed teachers and heads of schools in Schenectady, N. Y., each year for personal illness or on the occasion of serious illness or death in the family. The leave is cumulative in whole or in part. When 100 or more days have been accumulated, upon application to the board of education the teacher will be granted a half-year's leave of absence, on full pay, for study or travel, or for some other activity which in the judgment of the board will be of equivalent value to the school system.

SOME SIMPLE USES OF MATHEMATICS TO CLARIFY CHEMICAL PRINCIPLES.

By G. T. Franklin,

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Generally, the pupil's most recent experience with the mathematics when he arrives in the chemistry class is not arithmetic, but algebra. Partly for this reason, the teacher is exasperated to find certain pupils very slow in the solution of problems. After all, algebra is a sharper and easier tool than arithmetic. It often occurs to me to interest this type of pupil as much as possible to translate arithmetic into algebra wherever possible to do so, even creating some mathematics to express ideas that are ordinarily contained in words. After the pupil is familiar with "atom," "molecule," and has worried some with Avogadro's law to the extent of making application of it to the proof that there are at least two atoms in a molecule of certain gaseous elements, we work out together a little mathematics as follows: Suppose we have two boxes each holding exactly one liter, the one filled with hydrogen and the other with oxygen under the same conditions of temperature and pressure.

(1) Let x = number of molecules of oxygen.

(2) and m = mass of each molecule.

(3) Then, mx = mass of the oxygen = 1.44g.

(4) Let y = number of molecules of hydrogen in the other box.

(5) and n = mass of each molecule.

(6) Then, ny = mass of the hydrogen = .09g.

Dividing equation (3) by (6) we obtain

$$\frac{mx}{ny} = \frac{1.44}{.09}$$

But, x = y (Avogadro's law).

Therefore, $\frac{m}{n} = \frac{1.44}{.09} = \frac{16}{1}$.

Since $\frac{m}{n}$ is the ratio of the mass of a molecule of oxygen and a molecule of hydrogen, this ratio is 16/1. If 1 is regarded as the mass of an atom of hydrogen, the molecule is 2, and the atom of oxygen 16, the molecule 32.

Many pupils dread the study and application of certain gas laws, the most frequently used of which are the well-known

laws of Boyle and Charles. By the use of a little algebra the completely formulated equation involving both laws is obtained. Then, it is merely a matter of substitution in the equation to solve any problem involving the laws. It not only enables the pupil to solve the problem in chemistry but he gets valuable drill in the method used by engineers in the application of mathematics. No professional engineer ever stops to develop his mathematics every time it is used. It is largely a matter of inserting numbers for symbols and then applying the slide rule. However, I do not think anyone should make use of an equation unless at some time he either derived it for himself, or else followed with understanding its development by someone else. The pupils and I work through together the following systems of equations:

Pupils, who have not completed a third semester of algebra may not know what variation signs mean or the significance of a "constant." Both may be readily taught by the use of a simple type of problem. If a train is traveling at a uniform rate, the distance it has traveled varies directly as the time. This may be expressed in symbols as follows:

$$d \text{ (distance)} \propto t \text{ (time)}$$

Then, $d = Kt$. (K being the constant or in this case the rate). The pupil should see from one or two illustrations of this kind that the formidable looking symbol of the chemist known as his "constant" merely means some unit of measurement selected to fit a particular case and when once determined fits all cases involving the same substances though of different values.

Let V = volume of a gas and P = pressure, and T = absolute Temp.

(1) Then, $V \propto \frac{1}{P}$ (T = constant) Law of Boyle

(2) or $V = \frac{K}{P}$ (T = constant)

(3) also, $V \propto T$ (P = constant) Law of Charles.

(4) or $V = Kt$ (P = constant)

(5) Comparing (1) and (3), $V \propto \frac{T}{P}$

(6) or $V = \frac{KT}{P}$

(7) For a different temperature and pressure $V_1 = \frac{K_1 T_1}{P_1}$

(8) Dividing (6) by (7), $\frac{V}{V_1} = \frac{KT \times P_1}{KT_1 \times P}$.

(9) Canceling K from numerator and denominator and multiplying the equation by V, the expression becomes

$$V = V_1 \times \frac{T \times P_1}{T_1 \times P}.$$

By a little algebra, as in all equations of this kind, any one of the quantities may be written to the left of the equal mark. Any five being known, the sixth can thus be readily calculated.

EUROPE TO SAVE BEAVER.

Beaver, once almost wiped out in the United States, but now becoming re-established through wise protective measures, are now the objects of similar care in certain of the countries of Northern Europe, according to Dr. Theodor G. Ahrens, a well-known naturalist residing in Berlin.

There is a "beaver oasis" between Torgau and Magdeburg on the Elbe. Before the war there were 188 animals in it, but during hostilities it suffered from the inroads of poachers. Now, however, it is returning to normalcy, and it is estimated that there are 150 animals in the colony. In Prussia and Anhalt there is a permanent closed season on beaver. The willows around their streams are not cut, and new ones are planted for their benefit. Human beings are kept out of their preserves as far as possible.

The beaver are receiving protection in Russia also, though during the war and the early days of the revolution the animals here were badly persecuted and the morale of the survivors shaken, making them very restless and prone to migrate. It is hoped that through strict protective measures and the creation of reserves the beaver may increase and again become game animals.

However, by far the greater number of European beaver live in Norway; their total has been estimated variously as 10,000 to 14,000. Since 1926 they have enjoyed a permanent closed season, except that at the discretion of the Minister of Agriculture a few may be captured from time to time in certain designated districts. The present flourishing state of the beaver in Norway has been built up since 1899, when only a few of the animals were left alive. Norway even has beaver to spare for her neighbors, and Sweden expects to colonize her national parks from Norwegian stock.—*Science News-Letter.*

CRAPPIE AND CALICO BASS.

The Massachusetts Senate has recently been agitated by a proposal to regulate "the taking, possession, and sale of calico bass and crappie." In the heat of discussion one Senator rose to remark that he had lived on Cape Cod for forty years, but had never heard of calico bass or crappies!

He might easily have learned about them by turning to Webster's New International Dictionary, which records that the crappie is a North American fresh water fish found chiefly in the Great Lakes region and the Mississippi Valley, and that the name is also applied to a near relative of this mid-western crappie, known in the eastern States as the calico bass (Pomoxis sparoides). The same authority provides a picture of the calico bass, which is "an edible fresh water fish," and is allied to the sunfishes. Its name is due to its variegated colors.

NOTES ON THE UPKEEP OF A LEAD-ACID BATTERY UNIT.

By Sanford C. Gladden,

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In the course of the writer's work at the North Carolina State College of Agriculture and Engineering, the task of placing the battery set of the Department of Physics in good working order devolved upon him. The set comprised 72 cells similar to those used in Delco light plants. Fifty-three of the cells were rated at 80 ampere-hour capacity, and the remainder were of double that capacity. By means of a distributing switchboard devised by Professor C. M. Heck, head of the department, any number of the cells, from a single cell to the entire bank itself, might be connected to plug sockets in any laboratory, classroom or office in the department.

From the very flexibility of the unit, it was of the utmost importance that every cell be maintained in the best possible condition. But what was the best possible condition? How could one be certain that his particular unit was in proper shape to render the best service? In the endeavor to ascertain these standards, reference was made to several books on storage batteries and storage battery engineering, but with small success. In most cases the instructions given were so general in character that their application to the case in point was negligible; or else "rule of thumb" procedure was advocated. In the course of reading the various books, however, the writer noticed that certain principles were advocated by the various authors as pre-requisite to the most beneficial state of lead-acid batteries, and that these principles were carried out more or less by the general run of battery service men.

It is thought that a paper embodying these principles might be of service to others working with lead-acid batteries. No particular originality on the part of the writer is claimed, other than the collection of scattered facts into a component whole.

First of all, absolute cleanliness of the battery room is necessary. If a motor-generator set is used as charging source, the set should be kept free from accumulation of dust, the splashings from the oil cups removed with cotton waste, the generator commutator kept in a shining condition by the use of fine sandpaper, and the entire unit kept in good order.

The tops of the battery jars should be kept clean of any foreign matter. Spilt electrolyte should not be allowed to remain on the outside of a cell jar, since a direct connection between the

cell terminals may result, causing a slow discharge of the cell. If a corroded copper wire connector is situated near a cell jar, there is danger that some of the deposit may find its way into the jar. To prevent this, all corroded connectors should be removed and carefully cleaned. The application of vaseline to connectors reduces the corrosive action. It is hardly necessary to say that there must be no loose wires or metalic objects lying on the tops of the battery jars, since these are incipient causes of internal or external short-circuits in the battery unit.

A word of advice might be given at this point to the persons who handle the cells themselves. The irritant effect of sulphuric acid upon skin tissue is well known; and when there are broken spots in the skin tissue the irritation is painful to the extreme. If, however, one applies a liberal amount of vaseline to his hands before starting his work, or, better still, wears rubber gloves while working with lead-acid cells, this irritant effect may be eliminated. Ordinary household ammonia will neutralize the irritation produced by sulphuric acid.

The battery room itself should be kept in good shape. A good rule to follow is not to allow anything to be present in the battery room unless it is a definite portion of the unit, either in use or for testing purposes.

Of the same importance as the care of the battery room is the care of the individual cells of the battery unit.

The greater portion of battery troubles—forty or fifty per cent at least, is due to one factor alone—*neglect*. A lead-acid battery, if given the right sort of treatment, will respond by operating at its greatest efficiency; but if it is given haphazard care and attention, unsteady service occurs, soon resulting in the breakdown of a cell which had several years of service in store.

In order that a storage battery unit shall give the service that may reasonably be expected, it must be inspected, tested, and charged regularly, and a record of the condition and behavior of the different cells kept. By such a procedure, a defective cell can be located easily and the necessary additional charge, repair, and replacements made before the cell is ruined.

In other words, the general instructions for the upkeep of a battery unit might be summed up in three rules:

1. Keep the battery unit clean.
2. Give regular attention to the battery unit.
3. Keep a detailed record of the behavior of individual cells.

The first of these rules has already been discussed. The second rule will now be considered.

By *regular* attention is meant everything implied by the term. If the level of the electrolyte is below the water line, a haphazard method of adding distilled water will mean that sooner or later the level of the electrolyte will be allowed to fall below the top of the battery plates, with a possible injury to the plates as a result. Once a week the individual cells should be inspected to see whether the electrolyte is at the proper height or not, and distilled water should be added at that time.

The battery unit should be kept in a normal state of charge. The normal terminal voltage (on open circuit) of a single cell is from 2.0 to 2.2 volts, with an electrolyte density of 1.280. These values may vary somewhat depending upon the concentration of the electrolyte when first placed in the cell, the temperature of the cell, types of plates, and *previous treatment*. Any marked variance from these average values, however, should be sufficient cause for a careful examination of the cell.

A lead-acid cell is considered discharged when the electrolyte has fallen a certain number of points (i. e., from 1.280 to 1.240 would be a fall of 40 points). The actual specific gravity limit varies with the type of cell and the maximum specific gravity of the electrolyte employed. In general the limit of specific gravity is 1.100 to 1.150 and of the voltage about 1.7 volts.

The normal discharge rate is that current which will discharge the cell within a specified time. This time varies with the type of cell and the maker. For stationary cells, this time has been arbitrarily fixed at 8 hours. It is considered that the efficiency and ampere-hour output are in the best relation for average practice when the cell is charged and discharged at normal rates.

The charging current, and consequently, the duration of charge, may be varied through a wide range without seriously damaging the cell. One fact should, however, be kept in mind; that too high a rate of charge, causing violent gasing having the appearance of boiling, should be avoided, since this is an indication that most of the charging current is acting to decompose the water into oxygen and hydrogen, which are given off in the form of gas. In addition, the action of the bubbles of gas escaping from the pores of the plates and in "boiling" to the top of the electrolyte has a tendency to wash the active material from the positive plates. Since the active material of the positive plate softens with use and tends to fall from the surface of the plate to the bottom of the jar in the form of sediment, violent gasing of the electrolyte would hasten this shedding of material and, by

just that much, shorten the life of the battery unit. A small amount of gasing at low rates and for a short time, at the completion of a charge, is not objectionable; but violent gasing should be avoided.

When too high a charging current is used, the temperature of the cell increases, often causing the breakdown of the wood separators between the plates. There is always a tendency for wood in contact with sulphuric acid to become carbonized. This tendency is very much accelerated at temperatures in excess of 110° F; and if a battery unit is regularly operated at temperatures in excess of this amount, it will probably be necessary to renew separators in the entire unit prior to the cells having ended their useful life. The effect of impurities in the cell is much increased at high temperatures also; but the principal effect of operation at high temperature of a battery unit is its deteriorating effect on the separators and plates.

With these facts in mind, it is advisable to charge a battery unit at relatively low rates. Naturally, the lower the rate of charge the longer the time required to complete the charge. Preferably the maximum rate of charge should not exceed the normal rate for the cells in question. If the time available for charge does not permit this rate to be used, the charging rate should be higher at the start of charge and then reduced to the normal rate as soon as the cells begin to gas.

A good test as to the state of charge of a cell is that there be no change in the hydrometer reading greater than 0.003 (3 points) in readings taken every 15 minutes for an hour during the charging period.

Once a week, or once every two weeks if the drain on the battery unit is not great, the whole unit should be given an overcharge at the normal rate. This serves to liberate the sulphate in the plates which the regular charge failed to free, and also serves to counteract the effect of local action in the cells.

Sediment should not be allowed to accumulate to such an extent as to touch the bottoms of the plates, as this would cause internal short-circuits in the cell.

The form of record kept as to the behavior of individual cells may vary with the particular installation. Ordinarily an average cell is selected from a particular bank of cells as pilot cell for that bank; and a detailed record kept for that particular cell. This serves as a general indication as to the condition of that bank. If a certain cell in the bank lags behind the others in

gasing on the completion of a charge, or becomes excessively warm during the period of charge, it should be subjected to a careful examination. Once a month the specific gravity and terminal voltage of each cell should be recorded and those cells showing a marked variance from the average of the whole unit should be examined for short-circuits, shattered plates, and the like.

A typical form for a pilot cell record is given.

Pilot Cell for Bank No..... (Cells No..... to No....., inclusive)
Date.....

Cell No.	Sp. Gr. (Initial)	Term. Volt.	Charged		Rate of Charge	Sp. Gr. (Final)
			Start	End		

Water added.....

FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE.

By DUANE ROLLER,

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The secret of education lies in respecting the pupil.—*R. W. Emerson.*

Science has but one fashion—to lose nothing once gained.—*Stedman.*

Science is the topography of ignorance.—*O. W. Holmes.*

Why did not some one teach me the constellations and make me at home in the starry heavens which are always overhead?—*Carlyle.*

The beginning of wisdom is found in doubting; by doubting we come to the question, and by seeking we may come upon the truth.—*Abelard.*

In the discovery of the harmony between any one truth and all other truths lies the essential feature of an "explanation."—*Henry Crew, "General Physics."*

Advance information of the result of the Battle of Waterloo consolidated the Rothschild fortune. It is advance information, which may be of equal potential value, that research offers you.—*Arthur D. Little, chemist, in Scientific Monthly, August,* 1924.

Scratch a cynic and nine times out of ten you find a neurotic. Queerly enough, scratch too loud an optimist, and you will find a neurotic whistling to keep his courage up. Diogenes and Pollyanna are relatives under the skin.—*Abraham Myerson, neurologist, in "The Psychology of Mental Disorders," an authoritative little book written in non-technical language.*

WEATHER "PROVERBS."*

By Katharine Ulrich,

Oak Park and River Forest Township High School, Oak Park, Ill.

Have you ever tried using weather "proverbs" in connection with class work? I have found them valuable as a stimulant in connection with work on weather.

We begin the study of weather by telling pupils that our main object is to make each one of them an amateur forecaster. Just how this ability will be of practical value all through life is explained. After the first week of accurate checking and patient explaining, it requires no more effort to teach with this object as an end, than to teach any other way. Personally, I find it requires less energy and has the advantage that the pupils are "pulling with you." After a few successful forecasts have been made, everyone is desirous of acquiring this new ability. For best results it is wise to select a time of year when lows and highs appear more or less regularly, as there will be more opportunities for beginners to make forecasts, and therefore more interest and enthusiasm.

However, sooner or later there comes a time when pupils tire of the monotony of keeping daily records of weather conditions, especially if no exceptions to general rules appear. That is when I introduce the "proverbs." Each pupil is given a copy of the list and is encouraged to add new ones. I explain that some of the sayings may be true, while others are false, and that still others may be neither true nor false and yet have an element of truth in them. Pupils then study the list in the light of their knowledge and observation and check accordingly in column 1, 2, or 3.

Three or four "proverbs" are checked in class each day in addition to the regular lesson. The discussion involves many of the weather principles previously studied and often results in an animated debate, which is highly desirable. There is a renewed interest in all tiresome detail when one does not wish to give up a pet saying, and there are few pupils who do not at first believe that most of the "proverbs" are true. Meanwhile exceptional weather conditions are sure to be observed by all and can be taken care of in class as they occur. There is an

*This article is based on regular classroom work. Many teachers of geography have developed successful schemes and methods. Let other teachers enjoy a measure of your success by writing these up and sending to Geography Department Editor, Katharine Ulrich, High School, Oak Park, Illinois.

advantage to be gained in selecting a variety for each day's work, as then the same principles are reviewed many times instead of once and pupils are strengthened accordingly.

Some readers may think that it requires much equipment to manufacture amateur forecasters. We do have considerable equipment—barograph, stormoguide, mercurial barometer, hygrometers, thermometers, the daily weather map, etc. All these serve as excellent aids in this work, but I am never successful unless I can get a pupil to learn to "feel" and "see" the air for humidity, temperature, etc., and to then infer whether it is getting lighter or heavier—whether a low or a high is approaching. Most homes have no weather instruments aside from thermometers, and often they are not properly exposed. Therefore to function in the daily lives of pupils, weather study must develop the type of observation that the pioneers had. I have found the following "proverbs" of use as a stimulant when the job begins to drag. I hope other geography teachers may find them useful.

WEATHER "PROVERBS."

	Column 1 *True*	Column 2 *False*	Column 3 *Some Truth*
1. When the dew is on the grass, Rain will never come to pass.			
2. When the grass is dry at night, Look for rain before the light.			
3. When the grass is dry at morning light, Look for rain before the night.			
4. Three days' rain will empty any sky.			
5. A deep clear sky of fleckless blue, Breeds storms within a day or two.			
6. When the wind is in the east, It's good for neither man nor beast; When the wind is in the north, The old folk should not venture forth; When the wind is in the south, It blows the bait in the fishes' mouth; (It's in the rain's mouth) When the wind is in the west, It is of all winds the best.			
7. Evening red and morning gray, Speed the traveler on his way; Evening gray and morning red, Send the traveler home to bed.			

WEATHER "PROVERBS."

	Column 1 *True*	Column 2 *False*	Column 3 *Some Truth*
8. Red sky at the morning, Shepherds take warning; Red sky at night, Shepherds delight.			
9. If the sun goes down cloudy Friday, Sure sign of a clear Sunday.			
10. If a rooster crows standing on a fence or high place, it will clear; if on the ground, it doesn't count.			
11. Between eleven and two, You can tell what the weather will do.			
12. Rain before seven, Clear before eleven.			
13. Fog in the morning, Bright sunny day.			
14. Sun drawing water, sure sign of rain.			
15. If it clears off during the night, it will shortly rain again.			
16. If it rains while the sun is shining, It will surely rain again tomorrow.			
17. A circle around the moon means "storm." As many stars as are in the circle, so many days before it will rain.			
18. Sudden heat brings thunder.			
19. A storm that comes against a high wind, Is always a thunderstorm.			
20. The oak and ash draw lightning. Under the birch, cedar and balsam you are safe.			
21. East wind brings rain; West wind brings clear, bright, cool weather; North wind brings cold; [South wind brings heat (especially on Atlantic coast).			
22. The rain crow foretells rain,			
23. Tree frogs cry before the rain.			
24. Swallows flying low is a sign of rain; Swallows flying high is a sign of clearing.			

WEATHER "PROVERBS."

	Column 1 *True*	Column 2 *False*	Column 3 *Some Truth*
25. The rain follows the wind and the heavy blast is just before the shower.			
26. Hail brings frost with its tail.			
27. No weather is ill if the wind be still.			
28. Full moon brings fair weather.			
29. Look out for rain when: A slack rope tightens; Smoke beats downward; Sun is red in the morning; There is a pale yellow or greenish sunset.			
30. Rain with an east wind is lengthy.			
31. A sudden shower is soon over.			
32. A slow rain lasts long.			
33. Low clouds, swiftly moving, indicate coolness and rain; hard edged clouds indicate wind; rolled or jagged clouds indicate stormy wind; "mackerel" sky, twelve hours dry.			
34. All clouds bring not rain. Every cloud engenders not a storm.—Shakespeare.			
35. When the clouds are on the hills, they'll come down by the mills.			
36. To forecast is better than hard work.			
37. After great droughts come great rains.			
38. A little rain stills a great wind.			
39. Small rain lays great dust.			
40. Rainbow at night, sailor's delight. Rainbow at morning, sailor's warning.			
41. A snow, a rich year.			
42. The more snow, the more healthy the season.			
43. In March much snow, to plants and trees much woe.			
44. When the snow falls dry, it means to lie; But flakes light and soft bring rain oft.			

WEATHER "PROVERBS."

	Column 1 *True*	Column 2 *False*	Column 3 *Some Truth*
45. Blow the wind ever so fast, it will lower at last.			
46. If the wind do blow aloft, then of wars we shall hear oft.			
47. Ill blows the wind that profits nobody.			
48. North wind show de cracks in de house.—American negro.			
49. The wind does not always blow from the same quarter.			
50. Wind and fortune are not lasting.			
51. A foul morn may turn to a fine day.			
52. A right easterly wind is very unkind.			
53. After clouds, a clear sun.			
54. If there be neither snow nor rain, Then will be dear all sorts of grain.			
55. In the wane of the moon, a cloudy morning bids a fair day.			
56. A full moon brings fair weather.			
57. A bolt does not always fall when it thunders.			
58. A calm precedes a storm.			
59. The more violent the storm, the sooner over.			
60. A good winter brings a good summer.			
61. When summer is winter, and winter, summer, 'tis a sorry year.			
62. However bright the sun may shine, leave not your cloak at home.			
63. When the sun is the highest, he casts the least shadow.			
64. Winter's thunder and summer's flood never boded Englishman good.			
65. Under water, famine; under snow, bread.			
66. When it rains in August, it rains honey and wine.			
67. March wind and April showers bring May flowers.			

WEATHER "PROVERBS"

	Column 1 *True*	Column 2 *False*	Column 3 *Some Truth*
68. March grass never did good.			
69. If March comes in like a lion, it goes out like a lamb.			
70. April and May are the Key of all the year.			
71. A hot May makes a fat church-yard.			
72. A dripping June brings all things in tune.			
73. Calm weather in June sets the corn in tune.			
74. If it rains on Easter Sunday, it will rain on Sunday for six weeks.			
75. Whereever the wind is on Easter it will be for six weeks.			
76. A red sun has water in its eye.			
77. A cloudy night brings no frost.			
78. One can tell when a storm is coming: By the way your hair combs. By your bunion. When your game leg itches. By your rheumatic knee. By the way flies behave. By the way mosquitoes bite. By the way leaves rustle.			
79. You can tell how cold the winter will be: By the thickness of the corn husk. By the thickness of the onion's skin. By the thickness of animals' fur.			

FALSE ECONOMIES SHOULD NOT BE MISTAKEN FOR REAL ECONOMIES.

Waste in the administration of the schools was never condonable. At present it is especially necessary that all waste be eliminated before the public can be expected to grant more funds. The public is scrutinizing more closely than ever the efficiency with which its money is being spent. If the elimination of waste does not leave ample funds for the schools, the public stands willing and ready to furnish more funds; the elimination of waste is, however, a first prerequisite to the receiving of more funds.

In attempting to economize, false economies should not be mistaken for real economies. If the efficiency of instruction is impaired by an attempt to economize, such an attempt constitutes a false economy. When, however, a saving is made and the efficiency of instruction is not impaired, there is a *real* economy.—*From "The Business Administration of a School System" by Ward G. Reeder.*

FUNCTIONAL THINKING AS AN OBJECTIVE OF MATHEMATICAL EDUCATION.

By J. S. Georges,

The University of Chicago High School.

The purpose of education, broadly stated, is to discover and to develop the dominant interests and powers of the pupils, and to develop desirable habits of thought, achievements, and conduct, which will function properly and effectively to the best interests of the individual as well as the society. One of the great types of life's activities, perhaps the greatest and the most distinctively human type, is thinking—"the handling of ideas as ideas, the formation of concepts, the combination of concepts into other and higher concepts, the discernment of relationships between concepts, the coordination of relationships into laws applicable to life and the world." Consequently, the educative process makes special provisions for the development of correct habits of thought, and the acquisition of efficient methods of thinking. The purpose of this paper is to show that functional thinking is decidedly a desirable activity of the human life, and that functional thinking can best be attained through proper mathematical training.

Functional thinking is thinking in terms of quantitative relationships, and has its root in the power we have to associate one thing, or idea, with another thing, or idea. To think at all one must think in terms of quantities, or ideas, or concepts, which depend upon and are related to other quantities, ideas, or concepts. The world is infected through and through with quantities and quantitative relationships. We cannot evade quantities, for wherever we go, and whatever we do we must deal with the quantitative aspect of the world. To talk sense is to talk in terms of quantities. To say that the nation is large, or radium is scarce, or lead is heavy is to talk nonsense unless we modify these statements by how large, how scarce, or how heavy. Functional thinking permeates all thinking. Our ability to understand and appreciate new relationships depends, in a large measure, upon the knowledge of quantitative relationships already in our possession. For the broadening of this background the educative process furnishes a long series of experiences, which in reality are quantitative relationships, through the understanding of which the individual is to acquire efficient methods and correct habits of thought.

Mathematics as an integral part of the educative process is

concerned in the development of functional thinking. Because the subject of mathematics attains more nearly than any other subject the prototype of what is the best in functional thinking, it is better qualified than any other subject to reveal efficient methods in this type of thinking. The concepts, processes, and principles of mathematics for the representation and the interpretation of life and the world are unique. The genuine values of mathematical education lie in establishing correct habits of functional thinking in terms of these concepts, processes, and principles of representation and interpretation of the quantitative aspects of the world. This unique function of mathematical education has been made the chief and primary aim of the teaching of secondary school mathematics by the National Committee on Mathematical Requirements. Functional thinking is to be developed specifically through the acquisition of those ideas or concepts in terms of which the quantitative thinking of the world is done, the development of ability to think clearly in terms of such ideas and concepts, and the acquisition of mental habits and attitudes which will make this training effective in the life of the individual.

Functional thinking involves three distinct and at the same time related abilities: first, the ability to recognize mutual dependence between variable and varying quantities; second, the ability to determine the nature of the dependence or relationship between variable quantities; and third, the ability to express and interpret the quantitative relationship. These three abilities constitute the three stages in the application of the scientific method.

The notion of variation and dependence is not by any means peculiar to mathematics but is common and familiar to all life activities. The mathematical term function has been adopted and is used in common life. We say, for example, his temper is a function of his digestion, and we use the term exactly in the mathematical sense. It means that a certain relationship exists between his temper and his digestion, and that if the relationship could be determined we would know his temper if we knew how his digestion was working. The concept of mutual dependence and of reciprocal evaluation is exemplified in every turn of life and of the world. To say the cost of a suit of clothes depends upon the supply of cloth, labor, and style is to speak in terms of functionality. To surmise that success in any enterprise depends upon the experience, training, education,

personality, and the determination of the individual is to recognize functionality. The ability to recognize mutual dependence between variable quantities is a quality of the educated mind.

Variation and dependence in mathematics is incorporated in the concept of function. Function may be defined as a correlation between two variable quantities, called respectively the argument and the functional value, such that when the argument is assigned a value from the set of values constituting its range the value of the functional value is uniquely determined. Algebraic expressions such as $5x + 7$, $3x^2 - 2x + 10$, are functions of the argument x. It is evident that for every value of the variable x the function will have a corresponding value. The algebraic statement of variation always implies that the nature of the relationship between the quantities is known, which representation is not always possible in the case of many phenomena whose factors are known to be mutually dependent and inter-related. The determination of the nature of quantitative relationships is the real problem in the study and investigation of phenomena.

The study of quantitative relationships constitutes the outstanding problems of science and education. "It is not things themselves," says Henri Poincare, "that science can reach, as the naive dogmatists think, but only the relations of things." The study of relationships and their determination is the means whereby man is able to understand the laws of nature and to know the material world in which he lives. Life itself is made up of relationships—relationships which unite the individual to the society or the group of individuals of which he is a member, to the inorganic world and the forces of nature upon which he depends for subsistence, and to the other organisms with which he inherits the earth.

The study of relationships is of no less importance to the educator than to the scientist. We speak of the science of education, of scientific investigation in the problems of education, and of educational theories based upon scientific methods. What do these phrases signify? Notwithstanding the disparagement of the educational methods of investigation by people whose lack of understanding and appreciation of the problems of the educator creates a confusion in their minds regarding the methods of study used in the educational phenomena and the significance of the results, it is readily admitted that the quantitative relationships with which the educator

has to deal are of no less importance than those studied by investigators in the fields of physical, social, or economical sciences. If anything they are more complex, and their study of far reaching importance. The complex phenomena of education involve numerous factors whose mutual dependences and relationships are not often discernible, and if discernible, are not expressible in the precise and symbolic language of mathematics as are so many of the phenomena of science. Yet the methods employed in their study, in their observation and measurement, in the collection and recording of data, in the classification of data for the determination of significant and characteristic relationships, and in the interpretation of the nature of relationships, are no less scientific than the methods employed in the study of any other sets of quantitative phenomena. The efficient use of these methods, however, depends upon the ability of the investigator to determine the limitations of the scientific method when applied to the set of quantities involved in the specific phenomenon he is investigating. This fundamental attribute is acquired only through correct habits of functional thinking.

The recognition of the fact that a certain relationship exists between the factors of a phenomenon shows an advanced type of thinking, a scientific rather than a superstitious attitude toward life and the world. It is the first step in functional thinking; it may terminate there, or it may result in an endeavor to determine the nature of the relationship. However, a mere consciousness of the existence of quantitative relationships is not sufficient. The educated person should acquire an understanding and appreciation of the scientific methods used in their determination. Functional thinking must include an understanding of the quantitative method.

The quantitative method of analysis is the type of scientific analysis which is applicable to those aspects of a phenomenon which can be measured. Essentially the method consists of three separate yet interdependent steps, namely, the collection of data, the classification of data, and the interpretation of data.

First it is necessary to secure data concerning the factors which enter the phenomenon to be studied in order to use such information in the determination of the relationship. This is accomplished by observation and measurement. The phenomenon may be the heat producing qualities of certain foods,

the tensile strength of certain metals, the efficiency of factory employees, the effectiveness of a certain mode of instruction, the expenditures of the national government, or the relation between belief and desire. The measured results will vary with the field in which the quantitative method is employed.

Measurement is the tool par excellence of the quantitative method, and with the process of counting constitutes the dual foundation of the science of mathematics. Two different processes of measurement are used in the study of phenomena, both of which are treated in the elementary courses of mathematics; the direct, and the indirect measurement.

The process of direct measurement is based upon the determination of the number of units in the magnitude of a given quantity, hence it implies the adoption or choice of a unit of measure, and the operation of counting the number of times the selected unit is applied to the quantity. The choice of the particular unit depends upon the size of the object and the purpose of the measurement. The actual determination of the number of the units in the measured quantity is not always an easy task. Every measurement is an approximation of the exact number of units in a quantity, consequently, no human measurement is exactly correct or ideally accurate.

The process of indirect measurement is based upon the use of certain mathematical elements, such as line segments, angles, and figures; and certain mathematical processes and principles, such as similarity, proportionality, and congruence. The process is used whenever direct measurement cannot be employed, and gives a greater degree of accuracy than the direct method. The various mathematical processes of indirect measurement treated in elementary mathematics are: (1) the congruent triangle method, where a triangle is constructed congruent to the triangle, one of whose sides is the unknown distance to be determined; (2) the scale drawing method, where the figure containing the distance to be measured is drawn to scale; (3) the similar triangle method, where the unknown distance is found not from an exact drawing but by means of an equation or proportion in which the unknown distance is one of the four elements; and (4) the right triangle method, where the unknown distance is made a side of a right triangle, and its value determined by the use of a trigonometric function.

The second step in the quantitative method is the classification of data. The data are recorded in a statistical table,

arranged in rows and columns according to the characteristic similarities or differences, segregated or grouped, according to the purpose of the classification. A classification of data for one purpose may be entirely inadequate for another. For example, a classification of factory employees according to their nationalities may be significant to a social worker, but of no significance to a personnel manager who wishes to assign some persons to tasks requiring certain technical skills; but a classification according to the amount of previous experience and training would be very useful. A classification of the reading difficulties encountered in reading mathematical textual materials according to the mathematical processes, principles, and concepts would be useful to the teacher of mathematics, while a classification according to the principles of grammar and English usage would be of interest to the remedial worker in English. Thus one method of summarization of data would not serve all the uses to which the data could be put. The method of classification must be of such nature that the significant characteristics of the entities forming the class are revealed.

In the classification of data two types of measurements are to be noted: (1) data which form continuous series, and (2) those which form discrete series. A table representing continuous variation, that is the changes of a fact over a period of time, is called a historical table, while one representing the frequency of occurrence of variable facts is called a frequency table. Statistical tables are hence strictly functional in character. They represent relationships between measured quantities in the form of a one-to-one correspondence.

The third step in the quantitative method is the interpretation of data. The U. S. Census Reports, for example, contain many pages of classified and summarized data concerning the residents of the country—their ages, nationalities, occupations, and incomes. Certain definite relationships may exist between nationalities and occupations, or between occupations and incomes, which the analysis of the classified data may bring out. The method of analysis of the classified data will vary with the nature and the purpose of the study. The interpretation must render clear the meaning of the tabular data, and whenever possible, the nature of the relationship illustrated by the table.

Interpretation of data may point out the nature of the relationship between the elements of a class, or between two classes, by comparing their similarities or their differences. Such

mathematical principles as averages, modes, medians, variations or deviations from the average, ratios, index numbers, and coefficients of correlations may be used in the determination of the significance of a statistical table which warrants fairly safe and useful conclusions regarding the nature of the relationship.

Interpretation of data may also be made in terms of certain mathematical elements such as line segments, plane figures and curves. The graphical method may be used in connection with a statistical table to furnish a vivid picture of the data, and to furnish additional information which may serve to discern the nature of the relationship or correlation between the two classes of data. The basic mathematical idea involved in this method is the representation of number pairs by the points in the plane. Since each point in the plane is uniquely determined by its two distances from two arbitrarily chosen lines of reference, called the coordinate axes, each pair of corresponding numbers from the two columns of a table may be used to represent the two distances of a point. Joining all the points, corresponding to all the number pairs of the table, a geometric picture of the numerical facts results which may shed some light upon the nature of the relationship.

Various types of graphs are studied in elementary mathematics which may be used conveniently to interpret experimental data, especially when the problem under investigation is to determine the law or fundamental relationship between two quantities. Bars are used for simple comparison of sizes; subdivided bars, cross-hatched, are used to compare component parts; frequency distributions are shown by vertical bars or histograms, and by broken-line graphs; time variations are shown by line graphs drawn to arithmetical or logarithmic scales; and functional graphs to picture laws and relationships which are expressible in algebraic language.

The statistical and graphical presentation and interpretation of measured data serve to enable the investigator to infer, often correctly, the nature of the relationship. The ultimate goal is the discovery of the relationship and its statement in concise language. A vast number of the phenomena of the physical, social, and economic sciences yield relationships which are expressible algebraically, as formulas, though the phenomena whose factors are too numerous, such as the educational problems, present inter-relationships and dependences whose determination is not always possible. All algebraically stated relationships,

whether they are between abstract mathematical elements, or between facts obtained by experimentation, are statements of transformations. Transformation means variation and change according to some determined law. The mathematical theory of transformation is the logic of functionality; it seeks to establish laws and generalizations based upon the results of experience and experiments. Ability to express quantitative relationships as definite laws constitutes the third and final step in functional thinking.

(To be continued in the June issue)

BACKGROUND AND FOREGROUND OF GENERAL SCIENCE.

By Wm. T. Skilling,

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No. II. The Earth and Its Neighbors the Planets.

Children are born with the Ptolemaic system of astronomy. At any rate as soon as they begin to observe and admire the sky their philosophy becomes geocentric. When they have entered junior high school and taken a few lessons in general science a new conception of the universe should dawn upon them. They should in a week make the transition from the geocentric to the heliocentric philosophy, which the race required many generations of argumentation to accomplish.

A topic so fundamental as the solar system should not be lightly passed over in any course having for its aim the acquaintance of pupils with the rudiments of science. From a strictly utilitarian point of view there may have been some logic in the answer of a young man taking a civil service examination. When asked the distance to the sun he said he could not tell, but that he knew it was not near enough to interfere with his duties in the office he sought. Nevertheless there are doubtless good and sufficient reasons, perhaps growing out of natural human curiosity, why for some thousands of years the relation of earth to sky has intrigued man's attention. Certainly now is not the time to lay down this torch of knowledge which has been carried forward since the days of Aristotle even if other torches *will* give more calories of heat or cook more food.

Interest in astronomy among ancient Greeks was so great that as early as the sixth century B. C. the astronomer and mathematician, Pythagoras, began to recognize that the earth is round, and poised in space.

In the next century some of his successors went further and

discussed the possibility of the earth turning on its axis and revolving around the sun. This theory did not take deep root, however, in the thinking of that day. More influential in molding thought were the opinions of two great men, Hipparchus, in the second century B. C. and Ptolemy, in the second century A. D. Ptolemy wrote a book on astronomy which has been called the "Almagest." He summed up what was known in that day, especially the observations of Hipparchus, and based his reasoning on the theory that the earth is a stationary sphere around which everything revolves.

So great a hold did this book take upon the scientific world that its conclusions were not questioned for nearly 1400 years.

But in the same decade that Columbus began making history in the realm of discovery, a young student in Italy named Copernicus began laying the foundation for a new system of scientific thought.

Copernicus finally wrote a great book, as Ptolemy had done, but basing it on the theory that the *sun* is the center and that the earth and other planets revolve around it. The peculiar motions of the planets—the "wandering stars"—were very simply explained in Copernicus' writings as due in part to motions of the earth. Ptolemy's cumbersome explanations by means of "epicycles" could be abandoned.

To present to young pupils facts concerning the solar system the use of diagrams and models is as great a necessity as the use of maps in the study of geography. After blackboard drawings of the orbits encircling the sun more permanent sketches and models giving quantitative as well as qualitative conceptions should find a permanent abiding place in some part of the room. For example relative sizes of planets may be shown by cutting circles of colored paper of the following dimensions and pasting them on a square of manila paper. The diameters may be: Earth, 1 inch, Mercury $\frac{3}{8}$ in., Venus $\frac{31}{32}$ in., Mars $\frac{17}{32}$ in., Jupiter $10\frac{5}{16}$ in., Saturn $9\frac{3}{16}$ in., Uranus $4\frac{1}{32}$ in., Neptune $4\frac{3}{8}$ in. An arc of a circle made on a radius of $54\frac{1}{2}$ inches will give an idea as to the sun's relative size.

Relative distances from the sun are well shown on a strip of manila paper a foot wide and thirty feet long by placing a dot at one end to represent the sun, and drawing concentric arcs with radii as follows:

Mercury $4\frac{5}{8}$ inches, Venus $8\frac{5}{8}$ inches, Earth 1 foot, Mars 1 foot 6 inches, Asteroids 2 feet 9 inches, Jupiter 5 feet 2 inches,

Saturn 9 feet 6 inches, Uranus 19 feet 2 inches, and Neptune 30 feet.

A model to represent both sizes and distances cannot well be made within the limits of a room but the following model can be easily pictured in the imagination and will serve a useful purpose. It is constructed on a scale of one yard to a million miles both for sizes and distances.

Let the pupils imagine a level, circular field three miles in diameter with a 30 inch globe (or pumpkin) at the center to represent the sun. (Thirty inches will stand for the sun's diameter of 866,000 miles.)

Around this globe, at a distance of 36 yards from it, a small pea to represent Mercury may be thought to travel once around in about three months.

Beyond this an ordinary sized pea at 67 yards from the center represents Venus, and another pea 93 yards out (93 million miles) stands for the earth.

Mars is a small pea at 141 yards, and the asteroids are more than a thousand small grains of sand at an average distance of 250 yards.

The distances are now so great that they may be expressed in miles. Jupiter, as large as an orange, is about a quarter of a mile from the center. Saturn, another orange, is a half mile away. Uranus and Neptune, plums, are respectively a a mile, and a mile and a half out.

The above model serves a double purpose in that it gives not only *relative* sizes and distances but also, because of the scale used, it gives *actual* dimensions (approximately) in millions of miles.

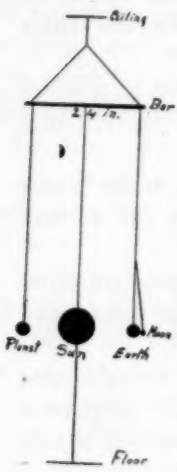
The model is so simple and the ideas involved so important that it is well worth while for pupils to commit it to memory. For convenience it is given below in tabular form.

Planets	*Size*	*Dist. from sun*	*Time to go around the sun*
Mercury	Small pea	36 yards	3 months
Venus	Pea	67 yards	7½ months
Earth	Pea	93 yards	1 year
Mars	Small pea	141 yards	1 year, 10½ months
Asteroids	Sand grains	250 yards	About 4½ years
Jupiter	Orange	¼ mile	12 years
Saturn	Orange	½ mile	29 years
Uranus	Plum	1 mile	84 years
Neptune	Plum	1½ mile	165 years

Model of Solar System Showing Relative Sizes and Distances. Scale: 1 yard = 1 million miles.

For a schoolroom model to show motions of the planets and the moon the one shown in the accompanying sketch is recommended. It is easily constructed, and possesses some advantages over the more expensive "planetariums."

A croquet ball or some still larger and heavier sphere suspended as shown from the ceiling of the schoolroom represents the sun. The earth and one of the other planets are shown by two small balls, which may be made to revolve as planets do. A still smaller ball held by a string about a foot long serves as the moon and will revolve around the earth three or four times while the earth goes once around the sun. Tennis balls filled with sand to give them weight may be used as planets.



The string by which this model is hung from the ceiling will twist allowing the planets and moon to revolve around the sun.

A little practice is necessary to learn to put all three in proper motion. The planet may be made to revolve in either a larger or smaller orbit than the earth. Rotation as well as revolution may be shown.

This simple model suspended in space is more realistic than are models mounted upon a table and controlled by geared wheels.

SHIP FEELS BUMPS OVER QUAKE.

Sailing over an earthquake that was sufficiently severe to be felt by seismographs throughout the world was the experience of a British ship, the Magalda, that has just been reported to the Hydrographic Office of the U. S. Navy.

Capt. W. S. Smales, the steamer's commander, reported that on December 1, while enroute from Talcahuano to Tocopilla, Chile, they felt three heavy bumps as if the vessel had struck bottom. Their position was latitude 35 degrees 33.5 minutes south and longitude 72 degrees 54 minutes west, where the charts show a depth from 400 to 600 feet. Careful examination showed that no damage was done.

As announced by Science Service at the time, the center of the quake was 35 degrees south and 74 degrees west, not more than 60 miles away from the Magalda's position. According to Commander N. H. Heck, in charge of the Coast and Geodetic Survey's earthquake investigations, the ship must have been very close to the center, or it would not have been felt as it was. The three bumps, he thinks, were due to three separate shocks, of which probably only one was severe enough to set up the earthquake waves which traveled around the earth and permitted the seismologists to locate it when they were received on the seismograph.—*Science News-Letter.*

TO WEIGH ELECTRICITY.

By Geo. P. Unseld,

West High School, Salt Lake City.

It may surprise some of our readers to learn that a charge of electricity can be measured and its voltage determined through the use of only such simple instruments as a pair of scales and a yard-stick.

To perform this interesting experiment all that is needed is two of the common spherical rubber balloons which can be bought for five cents each, a piece of fur or silk, a length of light string, small scales and weights, and a yard-stick.

As it is necessary to use centimeters and grams instead of inches and ounces in the calculations that follow it is better to use a meter-stick and scales that weigh in grams. But if these are not at hand inches may be reduced to centimeters by multiplying by 2.54, and ounces may be reduced to grams by multiplying by 28.4.

We first inflate the two balloons until they are 20 cm, about eight inches, in diameter and then tie the necks securely with a piece of string. The two balloons are made to weigh as nearly the same as possible by cutting off small bits of rubber from the necks. After weighing they are hung from a point near the center of the room by means of strings a yard or two in length, care being taken to have the distance from the point of support to the center of the balloon the same in each case. This distance is then carefully measured. In many cases it will be found best to tie the strings to the bottom of a chandelier.

The balloons are now electrified by rubbing them with the fur, a piece of silk, a clothes brush, or a woolen cloth. This should be carefully done so as to charge all of the balloon surface. In what follows it is supposed that each balloon has the same charge, which is not strictly true. However if both balloons are treated exactly alike the discrepancy here is not serious. While the second balloon is being treated care must be taken so as not to touch the first with the hand, the head, or in any way discharge a part of its surface.

As the balloons are now allowed to hang free it is seen that they repel each other, but are attracted by the hand or any other uncharged object brought near. If one is allowed to fall towards the other it will bounce it away even before it had come within a foot of the second balloon. It is as though invisible arms are reaching out from the spheres, causing repulsion. These are

called the "lines of force." The balloons are charged negatively as it is known that rubber when excited by any of the agents mentioned above acquires a negative charge. If an electrophorus is at hand it is seen that the balloons are repelled by the negatively charged base of the instrument, while they are attracted by the positively charged metal plate. The attraction of a positive charge is sometimes hard to distinguish from the attraction of any neutral body, as this body has a positive charge induced on that side nearer the balloons.

We now come to the only difficult part of the experiment. As the balloons hang free, no other body being near, the repulsion holds them a yard or so apart, and the supporting strings form the sides of an isosceles triangle. We wish to determine the distance between the centers of the balloons. If a measuring rod is brought near, the balloons immediately change their positions, being attracted to the rod. However, this distance can be estimated within an error of only a few percent by the following method.

One person stands from six to ten feet behind the balloons holding a rod in a horizontal position in a line parallel to one connecting the bottom points of the balloons. Another person stands in front and, sighting perpendicularly to a line joining the balloons, tells the first person when his fingers are placed at points on the rod immediately behind the bottom points of the balloons. The distance on the rod between the fingers is then measured. We denote this value by D.

We now wish to find the perpendicular distance from the point of support to the line joining the centers, which we designate as H. Also we call the distance from the point of support to the balloon center L. It is seen that L, H, and D/2 form the sides of a right triangle and that $H^2 = L^2 - (D/2)^2$. In an actual experiment the average weight of the balloons was 3.0 g, L was 100 cm., and D 64.2 cm. From this it is seen that H was 94 cm.

From the accompanying diagram it is seen that the balloon is at rest, being held in position by three forces; its weight which is downward and is 3 g, the force of repulsion which is to the left, and the pull on the string. The resultant of the first two is along the line of the string extended. From elementary geometry it is easy to prove that the triangle formed by the forces, half of the force parallelogram, is similar to the triangle formed by L, H, and D/2. Hence we have the proportion:

H : D/2 :: 3 g : F, or in the above example, 94.7 cm. : 34.1 cm. :: 3 g : F. Hence, F = 1.09 grams.

Before calculating the amount of electricity on the balloon it is well to consider the electrical units. It was first discovered by Cavendish and afterwards independently by Coulomb, that the force of attraction or repulsion between electric charges varies as the product of the amounts of electricity in the respective charges and inversely as the square of the distance between them. If we let e_1 and e_2 be the respective charges on the balloons, then, using the same letters to represent the distances, we have,

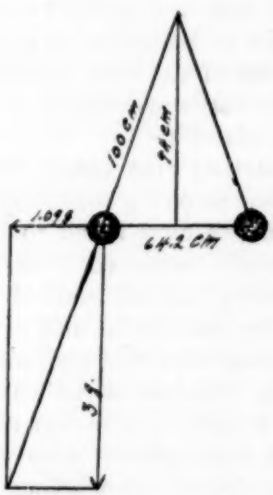
$$F = \frac{Ke_1e_2}{D^2}$$

Here K is a constant and depends on the units used.

We shall measure the charges, e_1 and e_2 in electrostatic units. An electrostatic unit of charge is such an amount of electricity that when placed one centimeter from an exactly equal and like charge the force of repulsion is one dyne. When these units are used, and D is measured in centimeters and F in dynes, K becomes unity. As we suppose the two balloons contain the same amounts of electricity, $e_1 = e_2$ and our formula is simplified to

$$F = \frac{e^2}{D^2}$$

From this we have $e = D\sqrt{F}$.



Before we can calculate the amount of electricity here present it is necessary to have the force of repulsion in dynes. A dyne is defined as such a force that, when acting on a mass of one gram

free to move without friction, the acceleration is one centimeter per second per second. By means of the Atwood's machine and other experiments it is known that when any force acts on a mass that is free to move the acceleration is directly proportional to the force and inversely proportional to the mass. Now when the mass of one gram is allowed to fall it has the acceleration of about 980 centimeters per second per second. This varies slightly in different parts of the earth, but is always between 979 and 981. Hence we can take the force or weight of one gram, caused by the attraction of the earth for the mass of a gram, as 980 dynes. Then 1.09 grams is 1070 dynes. Upon substituting the values of D and F in the above equation we have, $e = 68.2\sqrt{1070}$ or $e = 2230$ electrostatic units, the amount of electricity on each balloon. Due to the uncertainty in measuring D and to the fact that electricity is not distributed uniformly over the spherical surfaces it is not advisable to carry the calculations to more than three significant figures.

In the above calculations we assumed that the repulsive effect is the same as it would be were all the electricity concentrated at the centers of the balloons. This is indeed the case as was proved by Newton. The same mathematical reasoning that proves that the total gravitational force due to the many particles that make up a solid sphere is the same as if all the mass were concentrated at its center also applies to matter forming a thin spherical surface. And is true in case of any force, whether gravitational or not, as long as the force varies inversely as the square of the distance from that which causes it.

The amount of electricity that passes through an ordinary incandescent lamp in one second is very large indeed when compared with the amount we have found to be on the balloons. Electric current is usually measured in amperes. An ampere is such a flow of electricity that one coulomb passes by each second, the latter being the commercial unit of electrical quantity. Theoretical considerations show that the number of electrostatic units equivalent to one coulomb is the same as one-tenth the velocity of light in centimeters, or almost exactly three billion. An ordinary 100-watt incandescent lamp uses about one ampere of current, or one coulomb each second. If we divide three billion by 2,230 we have one and one-third million. It would require the electricity on one and one-third million balloons to supply such a lamp with current for only one second.

While it would require this *amount* of electricity for such a

lamp, yet it would not require as much *energy* as is represented by this number of charged balloons because the potential on the balloons is much higher than that used by the lamp, which is but a little over 100 volts.

We now wish to determine the potential or the voltage of the electricity on the balloons. Potential is a measure of the work a unit quantity of electricity can do. This depends, in a sense, on how tightly the electricity is squeezed together, as the work is caused by the repelling action of the lines of force. If a certain amount of electricity were placed on a metal ball two feet in diameter it would be capable of doing only half as much work as would be the case were the same amount placed on a ball only one foot in diameter. We can look at it in this way. In the second case the electricity is packed more tightly and the lines of force have more "spring."

The amount of work a unit charge of electricity can do when it flows away from a point of high potential is the same as the amount of work required to bring a unit charge up to the point that is at that potential. This is similar to saying that the amount of work a pound of water can do as it flows down a pipe to a turbine is the same as the work required to raise a pound of water up to the reservoir from which the first has flown. Also, just as one pound of water dropping through the vertical distance of 1,000 feet can do the same work as 1,000 pounds of water dropping through the distance of one foot, so one coulomb of electricity, one ampere-second, having the potential of 1,000 volts will do the same amount of work as 1,000 coulombs at one volt.

The electrostatic unit of potential is defined as follows: it is such a potential that one erg of work, one dyne-centimeter, must be performed in bringing one electrostatic unit of quantity from infinity, that is, from very far away, up to the point in question.

Now, if a unit amount of electricity is spread over a spherical surface the repelling effect acting on any charge as it is brought nearer and nearer the sphere is the same as though all the electricity on the sphere were concentrated at its center. If a unit charge is brought up then the ergs of work done, that is the potential in electrostatic units, varies directly as the amount of electricity because, at each point, the repelling force is directly proportional to this amount.

Now the larger the sphere that holds a certain quantity of electricity the less the amount of work required to bring a small

charge up to it because the charge is not brought so near to the center. Hence the potential of an electric charge on a sphere is determined by dividing the quantity of electricity on it by some number that depends on the diameter of the sphere. This number is called the capacity of the sphere.

A very simple calculation based on the laws and definitions given above, but one that involves the calculus, shows that the capacity of a sphere in electrostatic units is equal to its radius in centimeters. The balloons in the above experiment were 20 cm in diameter, and hence their capacity was ten units. The potential in electrostatic units then was 223.

We wish to reduce this last number to volts. A volt is defined as such a potential that one joule of work, 10,000,000 ergs, must be done in bringing one coulomb of electricity, 3,000,000,000 electrostatic units, up the point in question. This means that each electrostatic unit must have one three-hundredth of an erg of work performed on it. Hence one volt is one three-hundredth of an electrostatic unit, and these may be reduced to volts by multiplying by 300. From this we see that the potential on the balloons is 66,900 volts.

The reader is aware that this is a very dangerous voltage and is apt to question the result we have obtained. He must remember that the amount of work electricity can do depends on the quantity and on the potential. Compared to the amounts of electricity used in industry that on these balloons is almost nothing, and even though the potential is high, the amount of work, and hence the harm it can do is negligible.

Finally we wish to determine the amount of work represented by the charged balloon. If it were a metal instead of a rubber ball the electricity could be led off through a wire and caused to do work. But as the charge decreases the potential falls also because we have seen that the potential is directly proportional to the charge. It is given by the equation $CV = E$, where V is the potential and C the capacity. The average potential as the charge leaks off is just half the maximum potential or 111.5 electrostatic units. Hence 111.5 ergs of work are represented by each of the 2230 electrostatic units of quantity that was on one balloon. The total amount of work represented here is then 2230 multiplied by 111.5 or about 248,600 ergs. To reduce this to gram-centimeters we divide by 980, the result being 253 gram-centimeters. In other words, the charge on each balloon represents the same amount of work

approximately as that used in lifting 25 grams ten centimeters, or that in raising one ounce about four inches.

The joules of work are found by dividing the ergs by ten million. The charge on each balloon represents, then, .0248 of a joule. By definition a watt is power at the rate of one joule each second. Hence the charge on one balloon would furnish one watt of power for .0248 of a second. This represents enough energy to supply a 100-watt lamp for .000248 of a second.

We can arrive at this same result by another way. We assumed a one-hundred-watt lamp to take one ampere at 100 volts and found it would require the electricity on one and one-third million, or more accurately 1,345,000 balloons to supply this lamp with current for one second, neglecting the part played by potential. Now the potential required by the lamp is 100 volts and the average potential of the charge on the balloons as it dies away is 33,450 volts. This last number is 334.5 times the 100 volts. Hence, if potential is considered, each unit of quantity of electricity can do 334.5 times as much work as it would be able to do at 100 volts. Hence it would require but 1,345,000 divided by 334.5 or 4020 balloons to furnish the energy of 100 watts for one second. Then each balloon could supply 100 watts for one divided by 4020 or .000247 sec., the same result as before as the calculations are only approximate.

Note: In the Rocky Mountain region this experiment can be readily performed at any time, but in some localities, e. g., San Francisco, the humidity is so high as to make the electrification of the balloons all but impossible. In many sections the degree of success will depend on the weather. The author would appreciate it if those who try it write him of their success, as he wishes to know if it is difficult to find suitable weather in other parts of the country.

FLIES AID MEDICAL STUDIES

Flies which have long been held in bad esteem as spreaders of disease are about to do their bit in helping the human race. They are being used now for studies of the effect of X-rays on future generations. In flies, the harmful effects of these rays appear in the third and fourth generation, Dr. Mary B. Stark of New York City reported recently. She has exposed flies to X-rays for varying lengths of time While the individuals exposed continue to grow and breed, their descendants die off. Dr. Stark believes this is because the reproductive cells of the grandparent or great grandparent flies were injured by the rays. This injury is inherited and finally causes death. In this same way cancer may be produced in the third and fourth generations of flies. Dr. Stark believes that the experiments on flies will throw some light on this problem in human beings. Her theory is not accepted by all scientists, however. Because the human race breeds slowly, it will be some time before the inherited effects of X-rays can be noticed in man.—*Science News-Letter.*

A NEW TORQUEMETER.

By G. A. Peple and F. L. Robeson,
Virginia Polytechnic Institute, Blacksburg, Va.

The fact is generally recognized that even really serious students find it much more difficult to assimilate the laws of motion and the work and power relations for rotation, than for translation.

This seems to be due largely to unfamiliarity with the terms, radian, angular speed, torque, etc., in which the rotational information is expressed, combined with a time-honored tradition that this part of mechanics is exceptionally difficult. As a matter of fact, the principles of mechanics of rotation presented in the usual high school or first college course are not inherently more difficult than those of translation, save possibly in the sense that the fourth book of Euclid is more difficult than the third since it depends upon the third. The students nowadays are quite as familiar with revolutions per minute as with feet per second; but the scientific names mentioned above are encountered by them so infrequently as to retain the mystery of unfamiliarity.

The laboratory would seem the logical place to provide more encounters. The torsion pendulum, the inertia disc, the centrifugal-force machine, and the friction brake as applied to the water and the electric motor are more or less current in our laboratories; but they fail of their best training value if the student is allowed to substitute his observations in a formula already solved for the final result. In all cases where it is applicable, he should be required to determine torques and angular speeds and accelerations separately.

The torquemeter (Fig. 1) is a device which is perhaps more successful than any of those mentioned above in giving the student a clear idea of the quantities involved in rotational mechanics, because it measures the torque directly, thereby segregating the factors.

Though either end may be used as the driver, let us say that shaft 1 is connected by clutch or belt to the source of energy, the machine to be driven being similarly connected to shaft 6. The ball-bearing takes up the end thrust. Since shaft 1 is free to turn in bearing 7, any torque conveyed to shaft 6 must be transmitted by the spring 9 which is rigidly fastened at its ends to shafts 1 and 6 by collars 12,12. By Hooke's law, this torque is proportional to the angular displacement of 1 with

respect to 6. This displacement is communicated by the gear 2 to the smaller gears 3,3 which produce considerable rotation of the screws 4,4. These screws in turn move the nut 8, which is free to slide along 6, an axial distance proportional to the angular displacement, and therefore proportional to the torque.

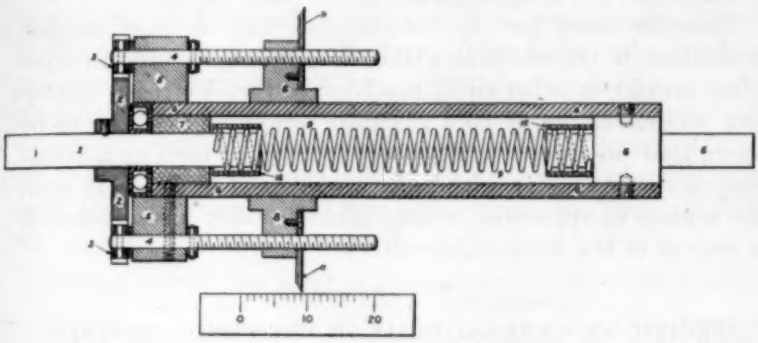


FIG. 1

A circular disc 11 attached to 8 makes it possible to observe this last displacement at any instant while the machine is running, on a stationary scale fastened parallel to the axis of rotation. The magnitude of the displacement for a given torque will depend, obviously, upon the stiffness of the spring, the number of teeth on the gears, and the pitch of the screws. The disc is steady in position and a vernier may be added, moved by the disc and sliding on the scale, if greater accuracy of reading is desired.

The apparatus is easily calibrated by clamping the barrel 6 in a vise, putting a cylindrical pulley (not crowned) on 1, and applying a couple to 1 by means of dead weights on cords leading from opposite sides of this pulley over small fixed pulleys. The calibration requires but a few minutes and should be a part of the experiment if time permits.

The torquemeter shows most clearly the greater torque required while bringing a flywheel up to speed, than is required to maintain the speed. This makes an excellent demonstration experiment. When used in power experiments, the speed of rotation is obtained by means of a tachometer or a revolution counter; and the product of the torque by the angular speed gives the power transmitted.

A complete dynamometer may easily be made from the

torquemeter by the addition of a speed-indicating device and a mechanism for giving mechanically the product of torque and speed. But having tried this out on our machine we think the advantages are not worth the trouble for ordinary work. There is also the disadvantage that the additional mechanism obscures the essential elements in the experiment.

Numerous uses for the torquemeter will at once suggest themselves: in the mechanics laboratory it may be used to drive a fan, grinder or other small machine; in the electricity laboratory, to deliver energy to a generator whose efficiency is to be determined; in the heat laboratory it may be used as a transmission dynamometer with any type of heat engine. It is in fact a piece of apparatus of very general utility in the research as well as in the student laboratory.

SPECIFIC VS. GENERAL DRILL IN THE FUNDAMENTALS OF ARITHMETIC IN GRADE FOUR.

By L. D. Morgan,

Kansas State Teachers College, Pittsburg, Kan.

Osburn[1] says that we should teach the child not what he already knows, but rather what he does not know. The only practical way to discover what the child does not know is to administer a diagnostic test. After the specific difficulties have been discovered by the diagnostic test, specific remedial measures should be administered to remove the specific difficulties discovered.

Mead[2] has shown the superiority of the Courtis Pads over that of Thompson's Essentials, and Evans and Knoche[3] have shown the value derived from using the Studebaker Practice Exercises.

Knight[4] has prescribed the specifications for drill if it is to be most effective.

The writer was interested in comparing the effectiveness of the Lenne's Pads with that of the Economy Remedial Exercise Cards in grade four. Fifty-six pupils were divided into two equal divisions on the basis of the average scores made on Woody-McCall's Mixed Fundamentals, and The Compass Survey Test in Arithmetic. The two sections were taught by the

[1]Osburn, W. J. Corrective Arithmetic, p. 178.
[2]Meas, Cyrus W. An Experiment in the Fundamentals, 1917.
[3]Evans, J. E. and Knoche, F. E. The Effect of Special Drill in Arithmetic as Measured by Woody-McCall and Courtis Arithmetic Tests. Journal of Educational Psychology, Vol. 10 (1919), 263-267.
[4]Knight, F. B. The Specifications for Drill. Third Yearbook, Department of Superintendence, N. E. A. (1926), pp. 63-64.

same teacher. The same amount of time was devoted to drill work in both sections. The division of the class was made the last of September. One group, which we shall call X, used the Lenne's Pad, the other group, Y, used the Economy Exercise Cards. Group Y was given a diagnostic test, one in addition, one in subtraction, one in multiplication, and one in division. Group X was not given a diagnostic test. Two weeks were given to practice in addition, then two weeks in subtraction, two in multiplication, and two in division. Then four diagnostic tests were again given to group Y. Then four weeks of intensive training were given on the four processes. At the end of the twelfth week the other form of the two tests, which were given at first, was given. The results are given in the table below.

AVERAGE OF THE TWO TESTS IN ARITHMETIC—WOODY-MCCALL AND COMPASS SURVEY TEST IN ARITHMETIC.

Group	Beg.	End	Gain	Diff.	S. D.	P. E. A.M.	P. E. Diff.	Index of Significance
Y	12.86	37.28	24.42	6.57	2.47	.317	.497	13.219
X	12.86	30.71	17.85		3.01	.384		

Conclusion. It would seem that for these two groups the Economy Remedial Cards and the Compass Diagnostic tests were superior to the Lenne's Pads. The rate of gain of the former over that of the latter is 43.23 percent. This gain is significant because the index of significance is 13.219, and when the index is four it is supposed to be significant.

For drill to be effective it must be specific, and remedial measures must be applied at the point of error.

FROGS LEARN GEOMETRY.

Frogs are not so dumb as they look. They can learn a simple proposition in geometry, as that a square is not a triangle. And they will remember their lesson for a little while, at least if they are paid for it.

A European experimenter, S. Biedermann, has reported the results of tests on the learning capacity of frogs. He set square and triangular blocks in pairs before his squat pupils. One block would have a delectable insect attached to it, the other would have nothing. After a sufficient number of repetitions the frog would learn that one shape was associated with the idea of food, the other with the idea of remaining empty; and when both blocks were presented without the accustomed bait the frog would hop expectantly to the one that had hitherto served as his dinner-table.

A number of different species of frogs and toads were thus "educated." Tree frogs proved to be the most apt pupils.—*Science News-Letter.*

A SMALL SIZE LANTERN SLIDE.

By Clarence R. Smith,
Aurora College, Aurora, Ill.

In modern photography there has come to be a decided tendency toward the use of smaller sizes. The 4 x 5 box camera of the old time amateur has long since given way to the "vest pocket" type and there have now come on the market several cameras which use motion-picture film for still pictures. That this tendency toward the use of smaller sizes is justified is evidenced by the truly wonderful results which are produced by these small negatives. A great factor in their success is the high degree of perfection with which lens systems can be developed for small areas.

In projection work, film slides are justly coming into great popularity. Here again optical perfection can be had at small expense. In their favor, too, is great economy of space and weight, both for machine and storing of slides.

In spite of the fact, however, that for many uses film slides leave nothing to be desired they have in other kinds of work certain handicaps for which improvements might be sought.

Where an entertainment or lecture is to be given repeatedly with exactly the same selection of pictures and the speaker is willing to adapt his lecture to the pictures on the film as purchased, a film slide is the thing. However, there is an extensive use for projection in school work, in college teaching for example, where the individuality of the teacher and the specific need of the occasion cannot be met by any fixed arrangement of, say fifty frames, on a film. Flexibility is the need. The teacher must be able to secure the pictures one at a time and insert or omit at any time for any occasion.

Another handicap with film slides for more serious uses is the lack of a sufficient labeling system. We mean a permanent label for each picture as a matter of record and explanation for the teacher, not merely a title frame now and then for the audience.

These considerations have kept film slides in a class by themselves and to meet the limitations mentioned, recourse has been had to the standard lantern slide with the heavy and expensive equipment involved.

In our school we have recently been experimenting with an idea which seems to offer great possibilities in this line. It consists in the use of a slide of the same dimensions as a standard

microscope slide (25 x 75 mm.) and in the middle of this a picture frame of the same dimensions as used on standard motion-picture film (19 x 25 mm).

Some of these slides we have prepared by cutting film strips between frames and attaching the individual pictures to ordinary microscope slides by means of lantern slide binding strip. Each of the four edges should be secured by the binding strip to prevent dust entering between the film and the glass. The emulsion side should be next to the glass and in use the glass should come nearest the source of light. A title and slide number is written on an ordinary square microscope label and attached at one end.

Other slides we have made by contact printing on ordinary lantern slide plates then with a glass-cutter trimming to a section 25 mm. wide and about 63 mm. long. This is attached to a microscope slide by means of lantern slide binding strip. A mat cut from black paper and placed between the pieces of glass before binding serves the same purposes as the mat in a standard lantern slide. Double thickness of glass should be avoided at the ends so they will fit into the grooves of ordinary microscope slide containers in which the slides will probably be kept. This method of preparing projection slides as compared with the preceding method of using cut film involved considerable waste of material and labor but was tried for the sake of the experiment. The product has a business-like appearance and will stand extensive handling. If the system should become popular, manufacturers could furnish supplies of suitable size to make it very convenient for anyone to prepare his own slides.

Compared with standard lantern slides these 25 x 75 mm. slides possess the following advantages: 1. Lighter weight and less space for storing. 2. More economy of materials. 3. Can be projected with a machine of far less expense for the same optical perfection. 4. Machine more portable.

The advantages over film slides may be summarized as follows: 1. Allow complete flexibility of selection and arrangement. 2. Room for label for each picture. 3. Can be stored in regular microscope slide containers which can be had cheaply and in a variety of forms and sizes. This also affords a convenient indexing system making it possible to quickly find any particular slide even from a large collection. 4. A machine for using these slides exclusively could be more simple

in design and have fewer "moving parts" than one for using film slides. 5. Convenience of making on the part of the user himself without the necessity of special printing and developing devices such as are required for film strip. 6. Possibility of staining or toning individual pictures.

We hope that other workers will give this system a trial. It may often happen in the regular economy of things that we find ourselves laboring under restricted efficiency in an established custom when at our very door there may be an improvement which can lead the way to much greater opportunities.

ALCOHOL FROM THE CHEMIST'S POINT OF VIEW.

By Dr. R. E. Rose.

Alcohol from the chemist's point of view is one of the most important substances made. It owes its origin to the fact that the little, single-cell yeast plants fight their enemies by turning sugar into alcohol and carbon dioxide. The yeast cell itself can not stand more than 15% alcohol, but its rivals fade away long before this concentration is reached, at least they become so stupefied that they do not count. The chemist is not much interested, as a member of his profession, in the advantages or disadvantages of the control of alcohol for drinking purposes. It amuses him to think of the "18th Amendment" in terms of molecules. Perhaps it would be terrifying to the rabid prohibitionist to know that a liquor containing one million times one million times one million times 16,000 molecules of alcohol in one teaspoonful would be still entirely legal, so that after all the human body can stand quite a number of alcohol molecules. Does not the near beer fiend drink a whole bottle without any visible signs of exhilaration, and it contains no less than one million, million, million, million molecules of alcohol.

Of course, the man who brews his own and can drink it, swallows quite a lot more, about 18 million, million, million, million molecules, and that number is sufficient to produce an effect if repeated frequently enough.

Alcohol is industrially of such immense importance for two reasons: first, that it is the most important solvent next to water, and dissolves a great many materials that water leaves untouched, and second, that it is the starting point for a perfect army of substances that are indispensable to the average human being, not always directly it is true. In making lacquers from nitrocellulose, lacquers that have become so tremendously important to the automobile and furniture trade, as well as to the trade in novelties and the like, alcohol is an essential because it can be converted into ethyl acetate, and ethyl acetate and ethyl butyrate are very good solvents for nitrocellulose.

The most widely used of all anesthetics that has been responsible for doing away with an infinity of pain and making it possible for the surgeon to save many lives, ether, is made directly from alcohol. In fact, if you could pick up two molecules of alcohol, hold them close together and pull off two atoms of hydrogen and one of oxygen, between the two you would have left a molecule of ether. The chemist uses phosphoric acid or sulphuric acid to pull the water out.

Ethylene, the gas that is used now to hasten the ripening of lemons, bananas, and the like, is also made from alcohol, but in this case you pull one molecule of water out of one molecule of alcohol instead of two.

Some of the most beautiful dyestuffs are made partially from alcohol, and others are made by using alcohol in the process of manufacture.

Altogether it is to the very great advantage of any people to have industrial alcohol available in unlimited quantities and very cheaply without any serious restrictions on its use for legitimate purposes.

NOTE ON DEMONS OF ELEMENTARY MATHEMATICS.

By MABEL SYKES, *Bowen High School, Chicago.*

An article appeared in the January issue of SCHOOL SCIENCE AND MATHEMATICS entitled "The Demons of Elementary Mathematics" by Wilbur C. Coit, of Seattle, Washington. The principal of the Bowen High School, Chicago, Illinois, Mr. Frank W. Stahl, was so much interested in this article that he gave some of the exercises in the Seattle test to 198 pupils in grade 9à of that school. These were pupils beginning the second half of ninth grade algebra. The results are given below. It did not seem wise to give the entire test, but the results are interesting nevertheless. The table below shows the questions given, the percent of failures on individual questions in the four Seattle high schools, in the Bowen high school and in the four groups in the University of Washington. The percents obtained in Seattle had to be estimated from the graphs published; consequently apologies are offered if they are not approximately correct. It will be noted that while the Bowen results are somewhat more uniform than the Seattle results, in general the higher percent of failures is on the same questions.

	Percent of failures								
	Seattle High Schools				Bowen High School	University of Washington			
Questions	A	B	C	D		1	2	3	4
Add									
—3a and 16a	11	14	10	13	2 1/2	24	28	30	30
+2b and +4a	22	38	62	42	35	46	40	52	76
—2 and 3/2	45	45	40	50	24	22	21	29	43
Subtract									
3 from —2	55	50	76	70	24	55	40	55	70
—9 from —6	48	40	72	47	22	62	43	43	73
1/4 from 1/2	17	30	20	20	22	35	10	21	21
Multiply									
2b by —3b	21	20	13	11	18	30	47	41	56
4 1/3 by 3/5	59	59	22	51	34	31	38	31	30
5 by 3/5	35	34	20	23	11	29	23	19	17
Divide									
—2b by 8	78	69	48	92	42	56	58	51	51
—2a by —3ab	85	80	80	72	67	58	70	58	59
4/5 by 2/5	30	41	10	40	25	33	33	27	37

PROBLEM DEPARTMENT.

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University of Michigan, Ann Arbor, Mich.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, 204 Mason Hall, University of Michigan, Ann Arbor, Mich.

SPECIAL NOTICE.

After June first send all communications to C. N. Mills, Illinois State Normal University, Normal, Ill.

LATE SOLUTIONS.

1049, 1051, 1052. *M. G. Schucker, Pittsburgh, Pa.*
1054. *J. Ross Adams, Rothville, Mo.*

SOLUTIONS OF PROBLEMS.

1055. *Proposed by E. de la Garza, Brownsville, Texas.*

Prove that

$$12^n - 11n - 1$$

is a multiple of 121.

Solved by C. F. Newton, Niagara Falls, N. Y.

$12^n - 11n - 1 \equiv (11+1)^n - 11n - 1.$

Expanding $(11+1)^n$ by the binomial theorem, and subtracting $(11n+1)$ we get an expression which is divisible by 121.

Also solved by *A. H. Heiby, Austin H. S., Chicago, Ill.;* and by the *Proposer.*

1056. *Proposed by R. L. Calvin, Youngstown, Ohio.*

Suggested by 1037. A hemispherical bowl, inner diameter 10 in., is half full of water. What is the diameter of a ball which can be put in and just covered with water?

Solved by E. A. Hollister, Pontiac, Mich.

The volume of the bowl is (250 pi)/3 cu. in.

The amount of the water in bowl is (125 pi)/3 cu. in.

When the ball is immersed the following relation is easily obtained, where r is the radius of the bowl, and $h = 2r$,

$$(125 \text{ pi})/3 + 4 \text{ pi } r^3/3 = \text{pi } h^2/3\ (15 - h),$$

which reduces to the cubic equation

$$12r^3 - 60r^2 + 125 = 0.$$

Solving this equation by Horner's method, gives $r = 1.8058$, or the diameter 3.612.

Also solved by *Norman Anning, University of Mich.; Raymond Huck, Johnston City, Ill.; J. Murray Barbour, Aurora, N. Y.; M. G. Schucker, Pittsburgh, Pa.; A. H. Heiby, Chicago, Ill.; George Sergent, Tampico, Mexico; C. F. Newton, Niagara Falls, N. Y.; John Carson, David Bender, Lewis and Clark H. S., Spokane, Wash.; S. M. Turrill, Maywood, Ill.;* and the *Proposer.*

1057. *Proposed by Secran.*

Each of the n digits of a number is 3. Prove that the square of the number is formed by writing in a row, from left to right, $(n-1)$ 1's, one 0, $(n-1)$ 8's, and one 9.

Solved by E. de la Garza, Brownsville, Texas.

$(333^n\ldots\ldots3)^2 = (999^n\ldots\ldots9) \times (111^n\ldots\ldots1)$

$$= (10^n - 1)\left[10^n - (888\overset{n-1}{\ldots}8)\ 9\right]$$

$$= 10^{2n} - 10^n\left[(888\overset{n-1}{\ldots}8)\ 9\ 0\right] + \left[(888\overset{n-1}{\ldots}8)\ 9\right]$$

$$= 10^n\left[(10^n - (888\overset{n-1}{\ldots}8)\ 9\ 0\right] + \left[(888\overset{n-1}{\ldots}8)\ 9\right]$$

$$= 10^n\left[(111\overset{n-1}{\ldots}1)\ 0\right] + \left[(888\overset{1-n}{\ldots}8)\ 9\right]$$

$$= (111\overset{n-1}{\ldots}11)\ 0\ (888\overset{1-n}{\ldots}8)\ 9.$$

Also solved by *J. Murray Barbour, Aurora, N. Y.; H. D. Grossman, New York, N. Y.; M. G. Schucker, Pittsburgh, Pa.; A. H. Heiby, Chicago, Ill.; Sudler Bamberger, Harrisburg, Pa.; C. F. Newton, Niagara Falls, N. Y.;* and the *Proposer.*

1058. *Proposed by the Editor.*

If in the triangle ABC angle $C = 60°$, prove that

$$\frac{1}{a+c} + \frac{1}{b+c} = \frac{3}{a+b+c}$$

Solved by Raymond Huck, Johnston City, Ill.

Clearing the given equation of fractions and combining terms we get

$$c^2 = a^2 + b^2 - ab. \quad (1)$$

By the *Law of Cosines,*

$$c^2 = a^2 + b^2 - 2ab\ \cos C. \quad (2)$$

But $\cos C = \cos 60 = \frac{1}{2}$, hence (2) reduces to (1).

Also solved by *S. M. Turrill, Maywood, Ill.; Norman Anning, Univ. of Mich.; Sudler Bamberger, Harrisburg, Pa.; H. D. Grossman, New York, N. Y.; J. Murray Barbour, Aurora, N. Y.; M. G. Schucker, Pittsburgh, Pa.; A. H. Heiby, Chicago, Ill.; George Sergent, Tampico, Mexico;* and *Mary E. Bolan, Fayetteville, N. C.*

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1059. *Proposed by Howard D. Grossman, New York, N. Y.*

If S_n be the sum of the legs and h_n the hypotenuse of an integral right triangle in which the legs differ by unity, then

$$(1+\sqrt{2})^{2n+1} = S_n + h_n\sqrt{2}$$

gives all possible pairs of values for S_n and h_n.

Solved by J. Murray Barbour, Aurora, N. Y.

Let X and $X+1$ be the legs of the right triangle. Then $S = 2X+1$, and $h^2 = 2X^2+2X+1$, whence $2h^2 = S^2+1$.

Assume the given relation is true, then

$$(1+\sqrt{2})^{2n+2} = (3+2\sqrt{2})(S_n + h_n\sqrt{2})$$
$$= 3S_n + 4h_n + (2S_n + 3h_n)\sqrt{2}.$$

Hence $S_{n+1} = 3S_n + 4h_n$ and $h_{n+1} = 2S_n + 3h_n$, from which we get

$$2h^2_{n+1} = S^2_{n+1} + 1.$$

Substituting the above values and reducing we get

$$2h^2_n = S^2_n + 1.$$

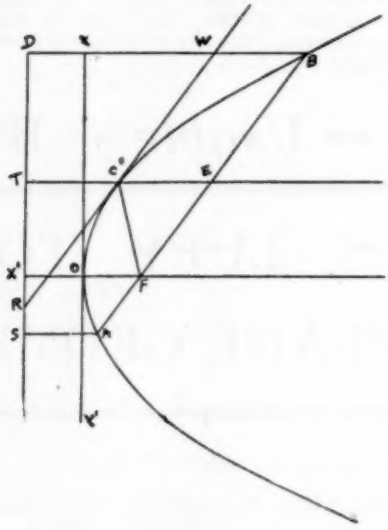
This proves that if the given relation is true for n, it is true for $n+1$. But the relation is known to be true for $n = 1$ or 2; viz., $(1+\sqrt{2})$ or $(7+5\sqrt{2})$, hence the relation is true for all values of n.

Also solved by the *Proposer*.

1060. *Proposed by George Sergent, Tampico, Mexico.*

Prove that any focal chord of a parabola is equal to four times the focal radius of the point of contact of the tangent parallel to the focal chord.

I. *Solved by Kate Bell, Spokane, Washington.*



RW is tangent to the parabola at C and AB is the focal chord parallel to this tangent. CM is the diameter from the point of contact; CF the focal radius; and DS the directrix. CM bisects chord AB at E. The diameter from the point of contact bisects the chords which are parallel to the tangent. Angle ECW = angle RCF. The angle between the tangent and the diameter from the point of contact is equal to the angle between the tangent and the focal radius to the point of contact. Since RW is parallel to AB angle RCF = angle CFE and angle WCE = angle CEF. Therefore angle CFE = angle CEF and CF = CE. Since any point on the parabola is equidistant from the focus and the directrix AF = AS, TC = CF, and DB = FB. Then TC = CE, and DB + SA = AB. TE = ½ (DB + AS) because TE is the median of trapezoid. Then TE = ½ AB and since TE = 2CF, AB = 4CF.

I'. *Solved by Albert Patterson, Wheeling, W. Va.*

Outline of Analytical solution.

Let the equation of the Parabola be $Y^2 = 4pX$. Then the equation of a tangent through (X_1, Y_1), a point on the curve, is $Y_1Y = 2pX + Y_1b$. The equation of the focal chord parallel to the tangent is $Y_1Y = 2pX - 2p^2$. Next find the points of intersection of the focal chord with the Parabola. The length of the focal chord is easily found to be $4(X_1 + p)$, which is four times the distance between the focus and the point of contact of the tangent.

Also solved by *R. T. McGregor, Elk Grove, Calif.; M. G. Schucker, Pittsburgh, Pa.; Raymond Huck, Johnston City, Ill.;* and the *Proposer.*

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PROBLEMS FOR SOLUTION.

1073. *Proposed by R. T. McGregor, Elk Grove, Calif.*

Given the base and the vertical angle of a triangle, find the locus of the center of the circle which passes through centers of the three escribed circles.

1074. *Proposed by the Editor.*

Find the value of i^i, where i is the square root of -1.

1075. *Proposed by Norman Anning, University of Michigan.*

Suggested by 1059. The hyperbola $X^2-2Y^2=-1$ passes through the point (p, q) where p and q are positive integers. Prove that the curve passes through the point $(3p+4q, 2p+3q)$, and that between these two points it does not pass through any point both of whose coordinates are integers.

1076. *Proposed by S. M. Turrill, Maywood, Ill.*

The parabolic bowl $X^2=4Y$ is filled with water to a depth of 5 inches. Find the diameter of a sphere that will be placed in the bowl that will cause the water to just cover the sphere.

1077. *Proposed by H. D. Grossman, Brooklyn, N. Y.*

Prove that the triangle of minimum perimeter that can be inscribed in a given acute angled triangle is the triangle formed by joining the feet of the altitudes.

1078. *Proposed by E. de la Garza, Brownsville, Texas.*

Find three numbers of which the sum is 36, and such that the product of the first by the square of the second and the cube of the third is a maximum.

SCIENCE QUESTIONS.

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PROBLEMS AND QUESTIONS FOR SOLUTION.

533. *Proposed by Lloyd V. Knox, Hawarden, Iowa.*

"Two lamps giving 16 and 32 candle-power respectively, are placed 200 centimeters apart. Where, between the lamps, may a grease-spot photometer screen be placed so that its two sides are equally illuminated?" (Black & Davis' *Practical Physics*, p. 471.)

a. Are *two* answers possible to this problem?

b. Suppose a student produces *two* answers, one of them being 82.9 in. from the 32 c. p. lamp; and the other -200, the latter obtained from solving the equation $\frac{(200-x)^2}{x^2}=\frac{32}{16}$, in its form $x^2+400x-40{,}000=0$, what mistake has he made?

534. *Was Socrates a Scientist?*

Irvin H. Myers brings an up-to-the-minute answer to this question in *The Atlantic Monthly* for February, 1929, under the title

Socrates Up to Date

A Dialogue Regarding Cause and Effect

(With thanks to *The Atlantic* for the courtesy which the Editor feels sure would be granted if asked.)

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Crito: It was Phaedo's street sign just below your bedroom.

Socrates: That cannot be, for the sign is there now, overhanging the street but I do not hear the annoying sound.

Crito: The reason you heard it last night and do not hear it now is that during the night it was swaying in the wind, but this morning it is motionless.

Socrates: Then it was not the sign but its motion, that was the cause of the offending noise.

Crito: Well, if you have to be so precise about it, let us say that the swinging or motion of the sign was the cause of the noise. The next time I see Phaedo I shall tell him I consider it an imposition to annoy the neighborhood with his creaking sign, when by dropping a little oil on the rod supporting it the sound would be done away with.

Socrates: How could the drops of oil stop the sign from swinging in the wind?

Crito: The oil would not stop it; it would cause it to swing more freely by reason of the lubrication.

Socrates: But I thought, to correct your first statement, you said it was the swinging or moving of the sign that caused the noise?

Crito: To be exact about it, I must beg leave to amend my explanation of the cause. It was the friction produced by the moving parts of the sign and supporting rod that caused the sound. To save you the trouble of asking another question, I will explain more fully, in anticipation, that the friction so produced causes minute rapid undulating movements of the supporting rod, which movements set in motion the surrounding atmosphere in the form of waves, which waves, beating against your tympanum, or eardrum, produce the sound.

Socrates: I hope I understand you now. If my eardrums were removed, there would be no sound.

To continue this interesting discussion read the February *Atlantic.*

Can we not get some of our ingenious young scientists to write up some similar discussions, say, on WHAT IS AN ELECTRIC CURRENT? Or, Why does a batted ball move?

TEST QUESTIONS.

531. *Questions from Harry E. Williams, Ironton High School, Ironton, Ohio.*

Try out these questions on your class and write your report to the Editor. *Send your own examination paper.*

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73. Put a plus mark before each statement if work is done. If no work is done place a zero before the statement. Each statement must have a mark.

a. A man lifts a piece of ice into the ice box.
b. A man pushes a wheelbarrow 100 feet.
c. A man holds a weight in his hand for two minutes.
d. A man lifts a weight from the floor to the table.
e. A man pushes against a box but is not able to move it.

74. The following statements are all applications of one definite principle. State the principle.

a. If a moving train is suddenly stopped by the emergency brakes, the passengers are thrown forward.
b. If a person alights from a moving car, he is sometimes thrown forward
c. The flywheel of an engine keeps moving after the power is turned off.

75. The following statements are all applications of one definite principle. State the principle.

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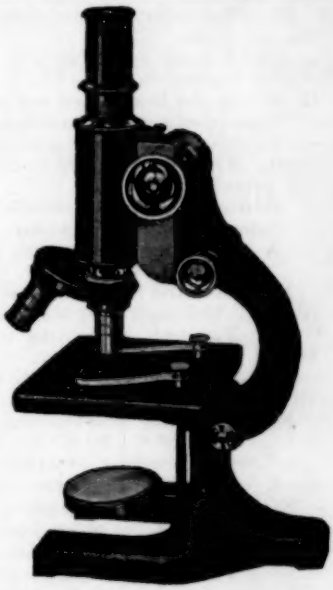

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a. The exploding powder in a gun barrel shoots the gun backward with the same momentum as it shoots the bullet forward.
b. We walk only because we can push backward upon the earth as hard as it pushes us forward.
c. A road pushes forward on the wheels of an automobile with the same force as the wheels push back on the road.

76. The following are all applications of one definite principle. State the principle.
a. The balancing of a see-saw by two boys, who weigh the same, at equal distances from the center.
b. The balancing of a see-saw by a 150-pound boy on one side 4 feet from the center and a 100-pound boy on the other side 6 feet from the center.
c. A boy finds that the nearer the wheel the load in a wheel-barrow is the less is the effort required.

77. The following are all applications of one definite principle. State the principle.
a. If friction could be eliminated, the same amount of work is done when a barrel is rolled up a plank into a truck as when the barrel is lifted vertically into the truck.
b. Neglecting friction a certain weight times the distance it is lifted by a jackscrew equals the effort required times the distance the effort moves.

78. The following are all applications of one definite principle. State the principle.
a. A boy sliding down a rope burns his hands.
b. Savages started fires by rubbing two sticks together.
c. The brake bands on automobile wheels get hot if the car is driven with the brakes on.
d. Car axles and the bearings of machinery if not properly oiled may be heated until they are damaged.
e. People sometimes warm their hands in cold weather by rubbing them together.

79. The following are all applications of one definite principle. State the principle.
a. There is less space between the rails of a railroad track in summer than in winter.
b. Rivets are heated red hot and in this condition are set and headed in constructing steel buildings and bridges.
c. In steam plants long pipes are provided with sliding joints.

80. The following are all applications of one definite principle. State the principle.
a. A stone weighs 10 pounds in air and 7 pounds under water. It displaces 3 pounds of water.
b. A metal weighs 15 grams in air and 10 grams under water. It displaces 5 grams of water.

In each of the following questions draw a line under the word or group of words that make the statement true.

81. The unit of volume in the metric system is the gram, quart, pound, liter, ounce, meter.

82. Standard atmospheric pressure in pounds per sq. in. is about 2.54, 10, 15, 20, 30, 39.37, 76, 100, 212, 273.

83. A definite mass of water has its smallest volume at 0° C., 4° C., 8° C., 10° C., 20° C., 39.37° C., 76° C.

84. In a vacuum a feather and coin fall together, feather falls slower than coin, feather falls faster than coin.

85. On a spring balance a given mass of sugar weighs more at the equator than at the poles, less at the equator than at the poles, the same at the equator as at the poles.

86. The rate of change of the speed of a moving object is called velocity, distance, acceleration, inertia, momentum.

87. Things that have a capacity for doing work possess centrifugal force, centripetal force, energy, friction, acceleration.

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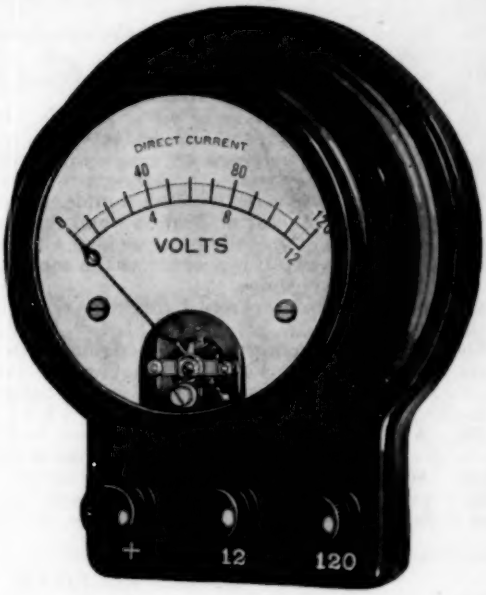

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88. The pressure in grams per sq. cm. due to a depth of water of 1 meter is 1, 6.24, 10, 62.4, 76, 100, 212.

89. A windlass used in drawing water from a well is a pulley, wheel and axle, screw, inclined plane, wedge.

90. Horse power is work done at the rate in foot pounds per minute of 427, 550, 980, 1,100, 33,000, 100,000.

91. When the barometer registers 76 cm., it registers in inches about 10, 15, 19.1, 29.9, 33, 34, 76, 100, 212.

92. The specific gravity of silver is 10.5. Its density in grams per cu. cm. is 1, 10.5, 21, 62.4, 6,552, 10,500.

93. For ordinary purposes of measuring temperature in our country we use the Fahrenheit scale, the centigrade scale.

94. Convection is poor in solids, liquids, gases.

95. A good conductor of heat is wood, air, copper, water, a vacuum.

96. One heavy stone falls twice as long a time as another heavy stone. The first one falls two times as far as the second, three times as far, four times, five times, six times.

97. Seventy-seven degrees Fahrenheit equal in degrees the centigrade scale 25, 42 7/9, 45, 60 5/9, 74 7/9, 81, 109, 138 3/5, 198 1/5.

98. The water pressure on the side of a tub 5 centimeters below the surface of the water is 5 grams per square centimeter. On a dam holding back a large lake the pressure 5 centimeters below the surface of the water is less than 5, 5, more than 5.

99. A needle can be made to float on water because of centrifugal force, gravity, surface tension, acceleration, Boyles' law, moment of force.

100. When the pressure is kept constant, the volume of gas is very nearly proportional to its absolute temperature. This is known as the law of Boyle, Charles, Pascal, Archimedes, Hooke.

BOOKS RECEIVED.

Economic Biology by George P. Weldon, Instructor of Biology, Entomology and Pomology, Chaffey Union High School and Junior College, Ontario, California. First edition. Cloth. Pages xi+457. 14x21 cm. 1929. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $2.50.

Modern Algebra, Second Course by Raleigh Schorling, Head of Department of Mathematics, The University High School and Professor of Education, University of Michigan, John R. Clark, The Lincoln School Teachers College, Columbia University and Selma A. Lindell, The University High School, University of Michigan. Cloth. Pages xvi+464. 13x19 cm. 1929. World Book Company, Yonkers-on-Hudson, New York.

Modern Algebra, First Course by Raleigh Schorling, Head of Department of Mathematics, The University High School and Professor of Education, University of Michigan and John R. Clark, The Lincoln School Teachers College, Columbia University. Cloth. Pages viii+391. 13x19 cm. 1929. World Book Company, Yonkers-on-Hudson, New York.

Walks and Talks in Numberland by David Eugene Smith, Eva May Luse and Edward Longworth Morss. Cloth. 182 pages. 13x19 cm. 1929. Ginn and Company, 15 Ashburton Place, Boston. Price 72 cents.

Plane Trigonometry by Carl A. Garabedian and Jean Winston, The University of Cincinnati. First Edition. Cloth. Pages xviii+306. 14x21 cm. 1929. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $2.25.

Theoretical Mechanics by Joseph Sweetman Ames, Provost, and, sometime Director of the Physical Laboratory and Professor of Physics The Johns Hopkins University and Francis D. Murnaghan, Professor of Applied Mathematics, The Johns Hopkins University. Cloth. Pages ix+462. 14.5x23.5 cm. 1929. Ginn and Company, 15 Ashburton Place, Boston. Price $5.00.

Descriptive Geometry by Harvey Herbert Jordan, Professor of General Engineering Drawing, Head of the Department, and Assistant Dean of

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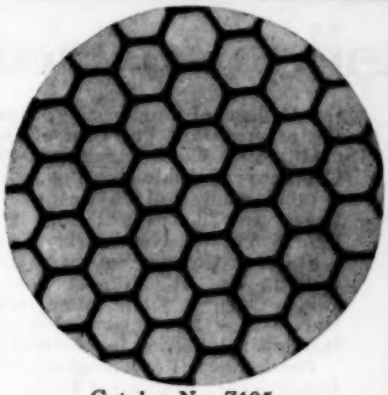

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the College of Engineering, University of Illinois and Francis Marion Porter, Assistant Professor of General Engineering Drawing, University of Illinois. Cloth. Pages xi+349. 14.5x23.5 cm. 1929. Ginn and Company, 15 Ashburton Place, Boston. Price $3.00.

Fundamentals of Physics by A. L. Fitch, University of Maine. Cloth. Pages xvi+336. 14x22 cm. 1929. Thomas Y. Crowell Company, 393 Fourth Avenue, New York. Price $2.50.

State of Connecticut State Geological and Natural History Survey, Bulletin No. 44. Report of the Water Resources of Connecticut by Roscoe Henry Suttie, Associate Professor of Civil Engineering, Yale University. Pamphlet of 168 pages and 7 figures. 14.5x23 cm. 1928. Hartford, Published by the State. Price $1.00.

Fundamentals of Chemistry by Carl William Gray, Head of Chemistry Department, Hollywood High School, Los Angeles, Claude W. Sandifur, Principal of Lankershim High School, Los Angeles, and Howard J. Hanna, Head of Physics Department, Los Angeles High School. Revised and Enlarged Edition. Cloth. Pages xiv+650. 12.4x19 cm. Houghton Mifflin Company, 2 Park Street, Boston. Price $1.80.

A History of Mathematical Notations by Florian Cajori, Professor of the History of Mathematics, University of California. Two Volumes. Pages xvii+367. 15.5x24 cm. The Open Court Publishing Company, Chicago, Illinois. 1929. Price $6.00 per volume.

Mechanical Drawing Instruction Sheets by A. K. Rigast, Head of the Department of Drafting, High School and Junior College, Eureka, California. Paper. Pages xi+79. 22x28 cm. 1929. The Macmillan Company, New York. Price $1.40.

Dynamics, A Text-book for the use of the Higher Divisions in Schools and for First Year Students at the Universities by A. S. Ramsey, President of Magdalene College, Cambridge; and University Lecturer in Mathematics. Cloth. Pages xii+259. 13.5x22 cm. 1929. Cambridge University Press. Price 10s. 6d. net.

BOOK REVIEWS.

Fundamentals of Chemistry, by Carl William Gray, Head of Chemistry Department, Hollywood High School, Los Angeles, Claude W. Sandifur, Principal of Lankershim High School, Los Angeles, and Howard J. Hanna, Head of Physics Department, Los Angeles High School. Cloth. Pages xiv+650. 14x19.5 cm., 1929. Houghton Mifflin Company, 2 Park St., Boston. Price $1.80.

This is a revised and enlarged edition of a text by the same title and used in many schools since 1924. Almost 200 pages have been added. A complete chapter is devoted to the electronic theory of matter; other chapters added are those on The Atmosphere, Soap, Paints and Lacquers, and the Chemistry of Agriculture. Oxygen and the atmosphere are introduced early, a wise improvement on the former text; a number of other chapters have been revised and rearranged in like manner. The authors have been especially successful in their aim as stated in the preface. "It is a strictly up-to-date presentation and is written in a simple manner so that it may be easily understood by the immature student." As in the previous edition the chapters on Valence and Formulas, and Equations are exceptionally clear and teachable. This text is replete with references to daily life and the industrial aspects of Chemistry. Numerous illustrations reenforce this practical information. Every chapter ends up with an Outline Summary; this should be very helpful for quick reviews as well as in encouraging the topical recitation. Reports on the latest advances in science rapidly come to the home by radio and the press, so that our chemistry students have many interests to be satisfied in addition to the elements of chemistry which must be mastered of necessity. This text has a wealth of readable information for the inquisitive student; it furnishes a rich field in which the more advanced students may browse while the rest of the class is getting the fundamentals. Many schools will find the features of this book just the ones they want for their chemistry courses. W. F. R.

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A Brief Course in Biology, by Walter W. Wellhouse, Associate Professor of Entomology, Iowa State College, and George O. Hendrickson, Instructor in zoology, Iowa State College. Pages xii+200. 53 figures. The Macmillan Company, New York.

This text is intended to form the basis for a college course in general biology running through two quarters or through one semester. It is written as a principles course illustrated by facts about a few selected types.

Approximately a third of the first half of the book deals with plant forms and two-thirds is given to the study of animals with little evident attempt at coordination of the two kinds of material. A concluding chapter shows inter-relationships of plants and animals. The latter half of the book deals entirely with animal forms.

The text is well written and while it is decidedly brief, references for the use of the student are given at the end of each chapter. This makes possible as much reading in connection with the work as seems desirable, and there is never any doubt as to the line of thought which the authors are attempting to develop; the objectives are not lost in a haze of detail.

Principles are not clearly indicated by chapter headings, but the key to the thought of the chapter is usually given in a statement near the beginning of the chapter. Chapter VIII is headed "A Hydra." In the second paragraph, the key is given as follows: "This animal, known as hydra, is of great interest because it is one of the simplest of many-celled animals that will enable us to continue the study of division of labor among cells."

The animal materials are handled in an excellent manner, but as a general biology text the book lacks balance and coordination in the use of plant and animal materials. Jerome Isenbarger.

New Practical Physics by Newton Henry Black, Assistant Professor of Education, Harvard University and Harvey Nathaniel Davis, President of Stevens Institute. Cloth. Pages x+645. 12.5x19 cm. 1929. The Macmillan Company, New York. Price $1.20.

This book is a revision of the very popular high school text, the first edition of which appeared in 1913. The authors believe that elementary students of physics are more interested in the applications of physical laws to their daily experiences than in studying the more theoretical notions of molecular physics and atomic structure. This idea is the guiding principle in this revision as it was in previous editions. The authors claim to have "minimized the arithmetical drudgery" in problem solving but a rather frequent criticism of previous editions is "too much arithmetic." These critics will have the same objection to the new edition, but to the reviewer the many numerical problems immediately following the principles involved are a necessary and stimulating part of every good physics text.

This revision consists largely in the addition of about sixty pages, much of which is made up of new pictures and diagrams illustrating the more recent advances made in color photography and the production of color scenes, talking movies, television, radio communication and air transportation. Paragraphs calling attention to the wonderful experiments with X-rays and crystal structure have been added. G. W. W.

A History of Physics, by Florian Cajori, Professor of the History of Mathematics in the University of California. Revised and enlarged edition. Cloth. Pages xiii+424. 13x20 cm. 1929. The Macmillan Company, 60 Fifth Avenue, New York. Price $3.50.

While a considerable number of rather minor changes have been made in the History as written thirty years ago, this revision consists principally in a narration and description of the progress of physics in the period which has developed the New Physics. To the young teacher and to the student now in college the developments of the early years of the twentieth century are as much a matter of history as the discoveries and theories of Newton and Faraday, and the author has exhibited no little skill in giving a brief but fairly complete outline of the steps in the study of radioactivity, the structure of matter, the quantum theory, the theory of relativity,

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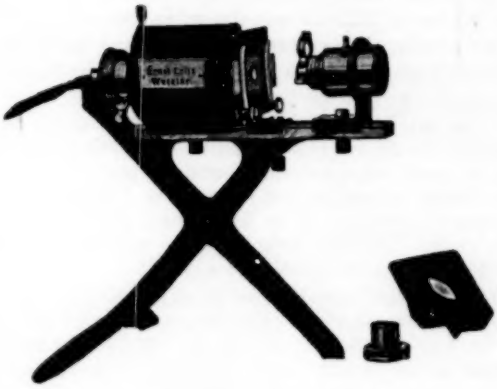

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wave mechanics, and other topics of modern research. Considerable care has been taken to give due credit to each contributor of this period and many interesting sidelights give us a more intimate acquaintance with the lives of these investigators. The final pages tell of the evolution of physical laboratories. G. W. W.

NEW GEOLOGIC MAP OF NEW MEXICO.

The first large colored geologic map of the entire State of New Mexico ever produced has recently been issued by the Geological Survey. New Mexico's 122,634 square miles present a great variety of geologic formations, topographic features, and mineral resources, and to show these formations the map has been printed in 17 colors, with 22 separate colors and pattern distinctions. It is an important addition to the knowledge of the geology of the United States. The map was prepared by N. H. Darton and sets forth the results of his own mapping, in part reconnaissance and in part detailed, and data from maps by many other geologists. It is printed in two sheets, which when joined measure 52 by 60 inches, and the scale is about 8 miles to the inch. The topographic base shows the configuration of the region by 100-meter contour lines.

The geologic formations shown on the New Mexico map represent many portions of geologic time—Cambrian, Silurian, Devonian, and Mississippian in the southern part of the State; Pennsylvania and Permian in wide areas mostly in the central part; Triassic, Jurassic, and Cretaceous in many districts; Tertiary in the San Juan Basin and the Staked Plains; and Quaternary in the valleys, especially the broad "bolsons" of the southwestern part of the State. The Tertiary formations include also some igneous rocks, and the Quaternary deposits are extensive accumulations of sand and gravel.

There are some marked general structural features in New Mexico. The eastern third consists of wide areas of plains and gently sloping plateaus, for the rocks are in larger part nearly horizontal. This district includes the Staked Plains, the Canadian Plateau, and the broad slopes adjoining the Pecos Valley. The San Juan Basin occupies a large rolling area in the northwestern part of the State and holds a great thickness of Upper Cretaceous strata, over-lain in part by sand and clay of Tertiary age. In the northwestern part of this basin are the oil-bearing domes that are now being explored. Extending from north to south through the center of the State nearly to El Paso is a line of interrupted ridges of uplifted older rocks, mostly steeply tilted and exposing in places the granite and other pre-Cambrian rocks. In the southwestern part of the State are ridges of various kinds due to uplifted strata ranging from Cambrian to Cretaceous in age, separated by wide vaileys. Volcanic rocks occupy large areas in New Mexico, constituting the high Mount Taylor, Sierra Blanca, and Valle Grande Mountains, rising more than 10,000 feet above sea level. Some recent lava flows are conspicuous in Tularosa Valley, on the east side of Zuni Mountain, and in the northeastern plateau area, where the huge cinder cone of Capulin marks the center of great eruptive activity at a geologically recent date.

The geologic map of New Mexico may be purchased from the United States Geological Survey, Washington, D. C., for $1.50 a copy, either in two sheets flat for wall use or folded and inserted in a cover about 19 by 26 inches.

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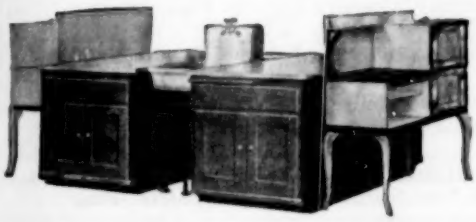

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The world's metal supplies in the rocks of the earth are showing signs of failing and experts are worried over whether the most efficient applications of science and technology can keep pace with the demands of coming generations. This state of low supplies in the mineral cupboards of the future was revealed to the meeting of the American Institute of Mining and Metallurgical Engineers in New York, when D. F. Hewett, geologist of the U. S. Geological Survey, discussed the production of metals in Europe during the last 300 years.

The European trend toward cartels and understandings to control such metals as iron and steel, mercury, aluminum, zinc, lead and copper, has arisen from the unspoken realization that Europe's metal production has taken a downward tendency, Mr. Hewett said.

In America vast resources of iron, copper, lead, zinc, silver, and gold have been attacked so vigorously that many leading districts are approaching exhaustion, and metal production is being maintained by the application of new metallurgical processes to lower grade ores. American mining operations are deepening shafts at a rate two to four times as fast as those of Europe, Mr. Hewett observed, whereas mines in Europe range from 1200 to 1600 feet in depth, American mines are often in excess of 4000 feet.

If we are willing to pay the price in fuel, power and labor, enough iron, manganese, aluminum and gold can be produced, Mr. Hewett indicated, but mercury, lead and chromium are more localized and less likely to be produced in sufficient quantities for future generations even if the price is increased to stimulate the supply.—*Science News-Letter.*

RECORD FOR BIRD FLIGHT.

The longest flight record ever reported to the Biological Survey for a banded bird was that of a fledgling Arctic tern, banded at Turnevick Bay, Labrador, on July 23 of last year by Oliver L. Austin, Jr. This bird was found dead on the beach at Margate, fifteen miles southwest of Port Shepstone, Natal, South Africa, on November 14. This is a remarkable record, not only for the distance covered, but for the time element, as the bird could have been only about three months old. It suggests the possibility that the birds, which are rarely or never seen on the South Atlantic Coast of the United States, may cross the ocean to Europe, and then proceed south.

The Arctic tern is well named, for it nests as far north as land has been discovered. It arrives in the Arctic region about June 15 of each year, and leaves about August 15 for its winter home, after its young are full grown. Several months after leaving its summer home this bird is found near the Antarctic continent, which is 11,000 miles from its starting point. It is estimated that at least 150 miles a day are covered on its migration flights, although ornithologists do not yet know its exact routes. Spending its life at opposite ends of the globe, the Arctic tern has more hours of daylight and sunlight than any other animal in the world. In the north the sun never sets during its entire stay, and in the Antarctic regions broad daylight continues throughout its sojourn there.—*Science News-Letter.*